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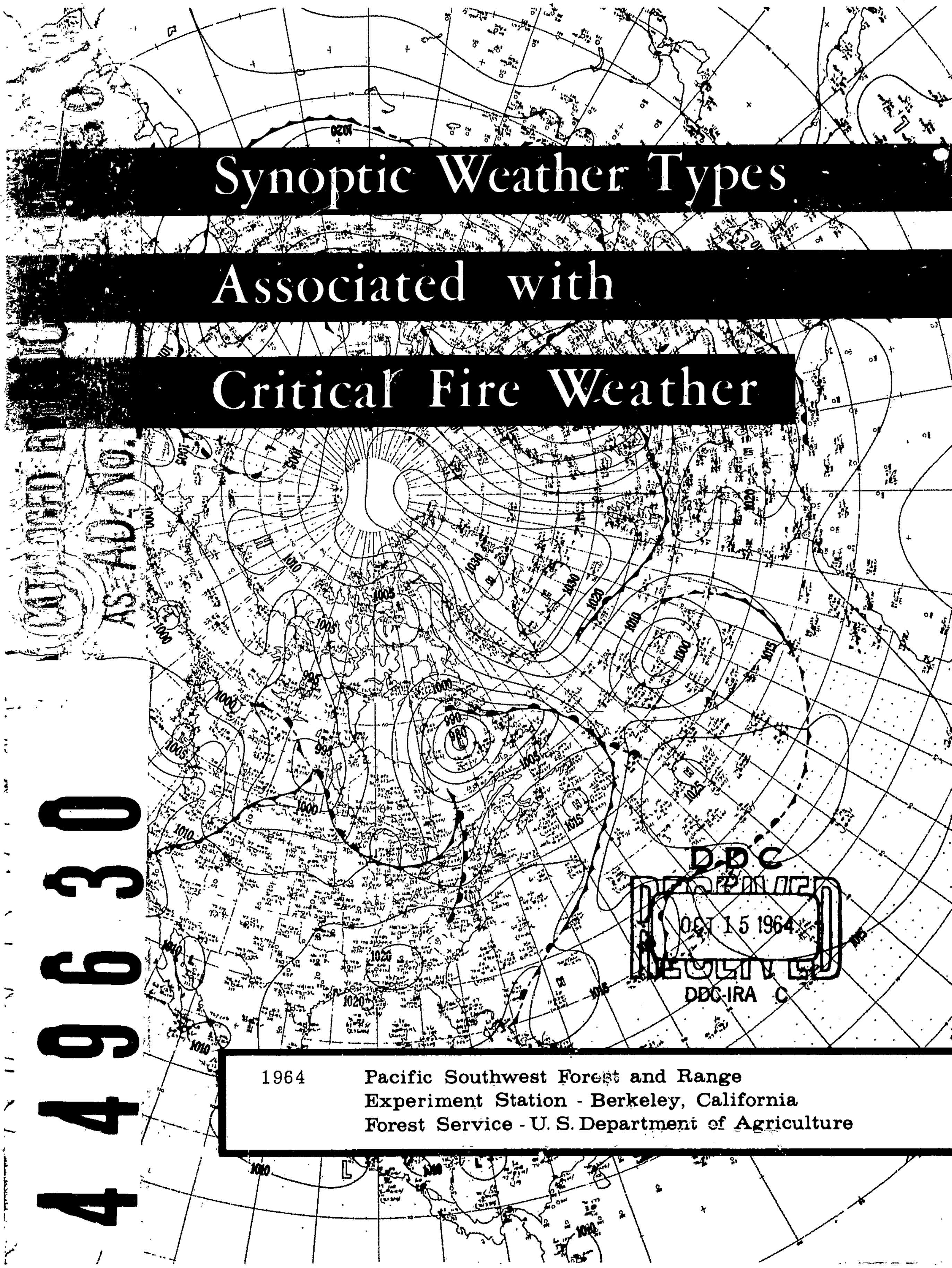
Synoptic Weather Types Associated with Critical Fire Weather



1964 Pacific Southwest Forest and Range
Experiment Station - Berkeley, California
Forest Service - U. S. Department of Agriculture

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SYNOPTIC WEATHER TYPES ASSOCIATED WITH CRITICAL

FIRE WEATHER

by

Mark J. Schroeder

and

Monte Glovinsky
Virgil F. Hendricks
Frank C. Hood
Melvin K. Hull
Henry L. Jacobson
Robert Kirkpatrick
Daniel W. Krueger
Lester P. Mallory
Albert G. Oertel
Robert H. Reese
Leo A. Sergius
Charles E. Syverson

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OCD REVIEW NOTICE

FOREWORD

In March 1962, a contract was made between the Office of Civil Defense, Office of Secretary of the Army, and the Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. This contract stated that the Forest Service "shall ascertain the major weather patterns producing critical fire weather nationwide and establish criteria for estimating their effect on mass fires in major target areas following large-area ignition by nuclear attack."

This report is confined to the first part of this objective. It describes the major fire weather patterns in each of 14 regions of the United States. The study of the frequency of occurrence of these weather patterns and the levels of fire danger that may be expected with each pattern is continuing and will be the subject of a separate report, tentatively entitled "Critical fire weather patterns--their frequency and levels of fire danger." A study of foehn winds in southern California, which is the major target area being studied first, will also be the subject of separate reports, tentatively entitled "Surface wind patterns in the Los Angeles Basin during 'Santa Ana' conditions," and "Three dimensional structure of foehn winds in southern California."

ACKNOWLEDGMENTS

This study would not have been possible without close cooperation between the U.S. Forest Service and the U.S. Weather Bureau. It is an excellent example of how agencies with related interests can work together toward the solution of a common problem. Through this cooperative effort, meteorologists who had the best knowledge of synoptic fire-weather patterns in each region of the country were able to participate in the project. The report has also benefited from technical reviews by Francis D. Beers, Fire Weather Supervisor, Weather Bureau Fire Weather Office, Portland, Oregon; William Innes, Jr., Meteorologist, California Division of Forestry, Sacramento, California; and Clyde A. O'Dell, Research Meteorologist, Fire Weather Research Office, Riverside, California.

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SUMMARY

Recognizing that weather is an important factor in the spread of both urban and wildland fires, a study was made of the synoptic weather patterns and types which produce strong winds, low relative humidities, high temperatures, and lack of rainfall--the conditions conducive to rapid fire spread. Such historic fires as the San Francisco fire of 1906, the Berkeley fire of 1923, the Chicago fire of 1871, the Bel Air-Brentwood fire of 1961, and the Hamburg firestorm of 1943 were undoubtedly influenced by the weather pattern occurring at the time. If critical fire weather periods can be predicted, preparations can be made to counter such disasters and reduce the damage they cause. But before such predictions can be made, the synoptic weather patterns must be identified.

Identifying Critical Periods

As the first step in this study, the 48 contiguous states were grouped into 14 regions, and the periods of critical fire weather were identified for each region. For this purpose the Wildland Fire Danger Rating System was used. It integrates various weather variables into fire danger indexes, weighing each variable according to its effect upon fire spread and fire intensity.

Of the various fire danger indexes comprising the Wildland system, the fire load index was selected to represent the fire danger due to weather because it incorporates all of the weather variables known to affect fire behavior into one index. Fire load indexes were computed for 89 stations each day in the 10-year period 1951-1960, using the afternoon weather observations and such supplementary weather information as was necessary. The level of fire load index selected to represent high fire danger varied from region to region so that the most critical fire periods in each region could be identified for study. This level of fire load index was 17 in the regions from the Mississippi valley eastward and 22 in the rest of the country except 37 in the Central Intermountain region, and 50 in the Southern Plains and the Southwest.

Determining Synoptic Patterns

Once the critical periods were identified, the next step was to determine the synoptic weather types associated with these periods. This was done by a study of surface and upper-air weather maps. Upper-air patterns were classified as meridional, zonal, block, or short-wave train. Surface anti-cyclones were classified according to their place of origin as Pacific, Northwest Canadian, Hudson Bay, or Bermuda. One type of anticyclone which tends to stagnate in the intermountain area was classified as a Great Basin High. From notes of these classifications, we related most of the periods of high fire danger to a

relatively few weather types. These types were then described. In some regions of the country the surface weather pattern was the important feature; in others, the upper-air pattern was important. To distinguish them, surface weather conditions are referred to as surface weather types and upper-air conditions as patterns.

The critical surface weather types are usually associated with an anticyclone. Highest fire danger is found on the periphery of the anticyclone where the pressure gradient, and therefore the wind speed, is stronger. In the West Coast states the important surface weather types were those that created an offshore flow. This usually occurred to the rear of dry cold fronts or in the area between a Great Basin High and a trough of low pressure along the coast.

In the western states upper-air patterns are closely related to periods of critical fire weather. A strong meridional ridge with a closed anticyclonic circulation produces heat waves in the far western states, while in the mountain and intermountain states high fire danger occurs on the east or west side of the upper ridge beneath the strong winds in the jet stream.

Regional Fire Weather Patterns and Types

Northeast region.--The critical fire weather season usually extends from April through October, and high fire danger is associated with four types: Canadian, Pacific, Bermuda Highs, and Atlantic Storm. The Canadian High includes cases with high pressure cells coming from either the Hudson Bay area or northwest Canada. The High moves southeastward near or through the northeast region. If it passes to the north of the region, the high fire danger tends to occur in the post-frontal area on the leading side of the High. If its center passes to the south of the region, the high fire danger tends to be in the prefrontal area on the western or northern side of the High. In the Pacific High type a portion of the semi-permanent Pacific high pressure cell breaks off, moves toward the northeast region, and affects the fire weather in much the same way as the Canadian High. The Bermuda High type is one in which the subtropical Bermuda High, normally located over the Atlantic Ocean, has a westward extension across the southern states. This extension cuts off Gulf moisture and results in warm, dry weather. High fire danger occurs in the northeast with the passage of weak fronts across the northern side of the Bermuda High. The Atlantic Storm type, which includes storms of both tropical and extra-tropical origin, occasionally produces high fire danger in the windy area beyond the rain shield if the air has a land trajectory.

Southeast region.--The critical fire weather season usually extends from March through November. There is a lull in July and August and occasional periods of high fire danger in the winter months. High

fire danger is associated with five types: Pacific, Northwest Canadian, Hudson Bay, and Bermuda Highs, and Tropical Storm. The Pacific and two Canadian Highs affect the Southeast in much the same way they affect the Northeast. The Highs take a more southerly course, however, usually because of a greater amplitude in the flow aloft. The Bermuda High type affects the Southeast region much more frequently than the Northeast. The Tropical Storm affects the Southeast in the same manner that the Atlantic Storm affects the Northeast.

Lake States region.--The critical season usually extends from April through October, and high fire danger is associated with four types: Hudson Bay, Northwest Canadian, Pacific and Bermuda Highs. The Pacific High accounts for more than one-half of the days of high fire danger and the Hudson Bay High more than one-fourth.

Ohio and Middle Mississippi valley region.--The critical fire weather is usually March through November, but periods of high fire danger occasionally occur in winter months. High fire danger is associated with the same synoptic weather types as the Lake States: Pacific, Northwest Canadian, Hudson Bay, and Bermuda High. The most critical fire danger areas are usually found in the warm sector or pre-frontal areas on the northwest side of the various Highs.

West Gulf States region.--The critical season is usually March through November, with a lull in June and July and occasional periods of high fire danger in winter months. High fire danger is associated with the same synoptic types as on the Southeast region: Pacific, Northwest Canadian, and Hudson Bay Highs, and Tropical Storm.

Southern Plains region.--Critical fire weather can occur almost year around. Fire danger indexes run higher than in the West Gulf States because the air reaching this region usually has a land trajectory. High danger is associated with five types: Pacific, Northwest Canadian, Hudson Bay, and Bermuda Highs, and Chinook. The Chinook winds, which are foehn winds, are observed along the eastern slopes of the Rockies and for some distance out into the Plains. Aloft the air flow is usually at right angles to the mountain range, while at the surface a High is located in the Great Basin and a front east of the Rockies. In the area between the front and the Rockies, air flows downslope, winds are strong, temperatures high, and humidities acutely low.

Northeast Plains region.--The critical season is April through October, with occasional high fire danger in March and November. High danger is associated with the same 4 synoptic types as in the Lake States: Pacific, Northwest Canadian, Hudson Bay, and Bermuda Highs. About two-thirds of the high fire danger cases are associated with the Pacific High type.

Northwest Plains region.--Critical fire weather usually occurs from April through October, and Chinook winds bring the high fire danger. Critical weather types were: Pacific and Northwest Canadian Highs, with associated Chinook, and Hudson Bay High. About 99 percent of the high fire danger days were associated with the Pacific High type.

Northern Rockies and Northern Intermountain region.--The critical season usually is from June through October, with isolated cases as early as March and as late as November. High fire danger cases were grouped into two types: Pacific and Northwest Canadian Highs. The Pacific High type accounted for 99 percent of the high fire danger days. In the case of a dry cold front passage, high fire danger may be found in the post-frontal area, but the more prolonged periods occur in the area on the west side of the surface High and the east side of a low pressure trough.

Central Intermountain region.--The season of critical fire weather extends from May through October, with short critical periods as early as March and as late as November. Periods of high fire danger were associated with: Meridional Ridge-Southwest Flow Pattern, Pacific High Type-Meridional Flow, and Pacific High Type-Zonal Flow. With the meridional ridge pattern aloft, the surface pressure distribution is flat and tends toward a trough. Peaks of high fire danger occur as short-wave troughs aloft pass over the region and influence surface winds. In the Pacific High types, portions of the Pacific anticyclone move into the region behind dry cold fronts. High fire danger occurs in the dry air and strong surface pressure gradients associated with frontal passages.

Southwest region.--The critical season is practically year around, with an annual minimum in winter months and a secondary minimum in August. The general level of fire danger is very high. The most severe fire weather cases were associated with three upper-air patterns: Meridional Ridge-Southwest Flow, Short-Wave Train, and Zonal Ridge. With each of these patterns, the critical fire weather occurs when the ridge is to the east and the trough to the west of the region. With the meridional and zonal patterns, the fire danger peaks when a shortwave trough passes over or slightly to the north of the region.

Pacific Northwest region.--The critical season is June through September, with occasional critical periods as early as April and as late as November. High fire danger is produced by surface air flow with an offshore component. There are two types: Pacific High with Post-frontal or East Winds and Northwest Canadian High with Post-frontal or East Winds. High fire danger occurs in the post-frontal areas of a cold front if the isobars are oriented so that the flow is from the northeast quadrant. Flow from this direction not only keeps the marine air offshore but also results in adiabatic

warming. If a portion of a Pacific or Northwest Canadian High moves into the area east of the Cascades, easterly winds are found in the region between this area and a trough along the Pacific Northwest coast, and high fire danger occurs west of the Cascades.

Northern and Central California region.--Critical fire weather usually occurs from June through September, occasionally as early as March and as late as November. High fire danger cases are associated with four principal synoptic patterns and types: Subtropical High Aloft, Meridional Ridge-Southwest Flow, Pacific High-Postfrontal Type, and Great Basin High. The Subtropical High produces heat waves. Winds may not be strong, but the atmosphere is usually quite unstable. Under southwesterly flow with a meridional ridge, the higher elevations away from the coast are affected by strong winds while coastal areas have a maritime climate. Post-frontal high fire danger in California is similar to that in the Pacific Northwest. The Great Basin High results in an east to west pressure gradient and causes the northeasterly winds of northeastern California and the Mono winds of the Sierra Nevada.

Southern California region.--Critical fire weather can occur year around. The synoptic fire weather types and patterns that bring high fire danger are similar to those in the northern and central portions of the state. They are: Subtropical High Aloft, Meridional Ridge-Southwest Flow, Pacific High-Post-frontal Type, and Santa Ana Type. The Santa Ana Type is essentially a Great Basin High and produces the most severe fire danger known. Strong northeasterly winds are found in the steep gradient area between a High in the Great Basin and a trough along the southern California coast. This flow descends the coastal slopes of the mountain ranges where the air is heated adiabatically. Winds may be 40 to 60 mph with gusts sometimes to 100. Temperatures frequently are mild even in mid-winter, and humidities may be less than 1 percent. Peak Santa Ana occurrence is in November and a secondary peak is found in March.

Conclusions

This study has shown that periods of critical fire weather are associated with a relatively few synoptic weather patterns and types. From the Rocky Mountains eastward most of the high fire danger occurs in the periphery of high pressure areas, particularly in the pre-frontal and post-frontal areas. Along the eastern slopes of the Rockies weather patterns producing Chinook winds are the most important. In the mountain and intermountain areas high fire danger is associated either with the presence of the jet stream overhead and the short-wave troughs moving along the jet stream or with the surface dry front passages. In the Far West patterns resulting in heat waves and patterns producing an offshore flow or foehn wind are important.

In this study the periods of high fire danger were selected first and then the synoptic patterns associated with them were determined. A study now underway will determine the frequency of occurances of these patterns and statistics on weather variables and fire danger indexes associated with them.

Several charts and graphs useful in long range Civil Defense planning are presented in appendixes:

1. A set of bar charts showing the distribution of fire load index values in percent frequency by months for each of the 89 stations in the network.

2. A set of graphs giving the accumulated percent frequency of fire load index values for each station by months.

3. A set of maps of the 25th, 50th, 75th, and 99th percentiles of fire load index by months.

4. A set of maps giving the probability of snow on the ground of 1 inch or more by 1 degree squares of latitude and longitude for each week from December through March.

INTRODUCTION

Damage from urban and wildland fires continues to be a tragic loss to the United States. Resources of many types are destroyed, homes and industrial plants are wiped out, and people are killed. In wildland areas particularly, the bulk of the damage is incurred during relatively few periods of critical fire weather. If we could identify the conditions which produce those periods so that they could be predicted, we could prepare for them and take steps to reduce the ensuing damage. The study reported here, which according to the enabling contract with the Office of Civil Defense was to "ascertain the major weather patterns producing critical fire weather nationwide", identified and described the major synoptic weather types associated with critical fire weather.

The study covered the 48 contiguous states. Because some regions are more prone to critical burning periods than others, the intensity of study differed among regions, depending in large measure on the uniformity, or non-uniformity, of those elements of climate important in fire weather. Although in most areas little or no critical fire weather exists during the winter months, the study included the entire year for a period of 10 years (1951-1960).

The association of weather with severe burning conditions is too complex for solution by a single study. Severe burning conditions are dependent upon other factors in addition to weather, notably fuels and topography. At one extreme there is no fire hazard regardless of the weather if there are no fuels to burn. On the other hand, burning conditions may be critical even under less than severe fire weather because of the amount, concentration, type and arrangement of fuels. Fuels, however, do not change appreciably in the time periods with which we are concerned. Nor does the topography. Weather is the variable factor. This study was therefore limited to the periods when the weather conditions are such as to favor fast-spreading, high-intensity fires if exposed fuels are present in sufficient quantity and concentration.

The existence of nuclear and incendiary bombs makes the ignition of mass fires particularly threatening. The damage resulting from attacks with these weapons will depend largely upon the availability and flammability of fuels in the area surrounding the target, and upon the weather parameters that influence the spread and intensity of the initial fire and peripheral spot fires. Under some weather conditions, such as the dry foehn-type wind of the mountain areas of the West, and with fuels available, major conflagration would be likely and virtually uncontrollable. Under less severe weather conditions fire-control efforts on the edge of the mass fire and on the spot fires could be carried out with a good possibility of success.

Implications for Civil Defense Planning

Knowledge of impending critical fire weather in different regions of the country would be extremely useful in devising and putting into operation emergency fire-fighting measures in advance of actual ignition. Before the periods of critical fire weather can be forecast, the synoptic weather patterns that are associated with severe burning conditions must be known. The great value of this study to Civil Defense planning is the prospective improvement in the prediction of periods of critical fire weather.

The results of this study should make the prediction of critical fire weather periods by fire-weather meteorologists more accurate, and assist in the training of new fire-weather meteorologists as they enter this field. Meteorologists serving as suggested in the Rural Fire Defense Plan could make a direct application of the results in interpreting current weather maps and prognostic maps available from the National Meteorological Center.

Material contained in the Appendixes of this report will also be of direct benefit to Civil Defense in long-range planning. Appendix A contains charts and graphs which give a measure of the monthly levels of fire danger experienced at each of 89 cities during the 10-year study period. Since this 10-year period contained a good sampling of severe, moderate, and easy years, taking these data as expected levels of fire danger over long periods should produce good results in long-range planning. Maps of fire danger by months, also included in Appendix A, should be useful in long-range planning where the area picture is an important consideration. Appendix B contains maps of snowcover probability by weeks for the months of December through March. This information also should be of direct benefit to long-range Civil Defense planning.

Weather during Historic Fires

The spread of fires, whether in cities or forests, is largely dependent upon weather conditions. Fuel exposed to the environment changes in moisture content with changing weather conditions. And it is well known that wind is an important factor in the spread of urban as well as wildland fires.

The combination of low humidities, high temperatures, and strong winds has often produced conditions under which urban fires burn intensely and spread rapidly. The Berkeley fire (Andrews and Rains 1923) burned a large part of this California city as a direct result of the prevailing weather conditions. The fire started in a brush area and was carried into the city by strong northeast winds at a time when the humidity was low and the temperature was high. It was not controlled until the northeast wind stopped and a sea breeze brought cool, humid, marine air into the area.

The spread of the San Francisco fire of 1906 was also related to the weather pattern (Williams 1956). At the time of the fire a high pressure area had moved into the northern Great Basin, and warm, dry northeasterly winds blew across the central California coast. Fire broke out in the eastern portion of the city and was carried westward across the city by offshore winds. The offshore flow continued for 3 days, and the fire was not stopped until westerly winds brought in cooler, more humid air from the Pacific Ocean.

The conditions creating critical fire weather are frequently related to the synoptic weather patterns and cover wide areas. It was no mere coincidence that on the same day in 1871 on which 250 persons and a third of the city were wiped out in the Chicago fire (Musham 1941), 1,500 persons were killed and 1,250,000 acres burned in the Peshtigo fire in Wisconsin, and 2,500,000 acres burned and an undetermined number of people perished in fires that raced across the lower penisula of Michigan (Holbrook 1943, Davis 1959). Critical fire weather prevailed in the entire Lake States region.

The Bel Air-Brentwood fire in Los Angeles in 1961 (Wilson 1962), which consumed more buildings than any other single conflagration on the North American continent since the Berkeley fire, occurred during a weather type known as the Santa Ana. This foehn-type wind, with its high speeds and attendant low relative humidity, creates the most severe burning conditions known anywhere. In extreme situations fire-fighting forces are helpless to control the head of a fire until the weather situation changes.

The firestorm in Hamburg, Germany, resulting from a bomb attack on the night of July 27-28, 1943, was undoubtedly influenced by the weather pattern. A study of the associated weather (Ebert 1963) has shown that from July 24-28 the Hamburg area was under the influence of a weak anti-cyclonic pressure ridge that extended from the Azores northeastward toward the White Sea. This pattern did not produce strong winds in the Hamburg area, but the associated subsiding air, clear skies, high temperatures, and relatively unstable atmosphere were conducive to the development of a large convectional system.

We should emphasize that this study gives a "broad brush" treatment to the problem of critical fire-weather periods. Only the synoptic scale is considered. Obviously many instances of high fire danger can be found which are not accounted for by the weather types and patterns described in this study. Many of these instances may be due to local effects such as the various facets of topography. Others may be due to weather patterns on the meso-, topo-, or even micro-scale. Also one may find within an extensive area occurrences of high fire danger associated with synoptic patterns other than those identified in this study. Other critical fire-weather types occur so infrequently that they cannot be identified. The types described here are periodic. They occur over and over again and account for the vast majority and the most severe of the high fire danger periods.

METHOD FOR SELECTING CRITICAL FIRE WEATHER PERIODS

Before the synoptic weather types associated with critical fire weather could be studied, some method had to be found by which periods of critical fire weather could be identified. The best way to do this would be to integrate the weather variables into one or more fire danger indexes according to their effect on fire spread and fire intensity. A number of fire danger rating systems are in use in the United States. They are usually designed to estimate in one way or another the effect of weather on the fire control job. Of the present systems, we considered the Wildland Fire Danger Rating System used in California and a few other areas the most applicable to nation-wide fire problems. This system had been programmed for machine computation of the indexes and for this reason also was ideally suited for the calculation of indexes for a large number of stations over a long period of time.

When the study was planned, we divided the country into regions based on topography and climate. As the study progressed we found little difference in fire danger between certain adjacent Eastern regions and therefore combined some small regions into single, larger ones. In one case in the West, a narrow strip along the California coast was not made a separate region even though it has much lower fire danger on most days than the area farther inland. The same synoptic patterns that bring high fire danger to this coastal strip also bring high fire danger to the inland area. Therefore, the coastal strip and the inland area were treated as one region, and the differences in fire danger were noted in describing the synoptic patterns. The final division of the country produced 14 regions (fig. 1).

Weather Station Network

A nation-wide network of 89 stations selected to represent the weather varies in density (fig. 1) with the homogeneity of the weather. East of the Rockies the stations are rather far apart because of the uniformity of the weather. From the Rockies westward the stations are closer together because the topography makes the climate more complex; each station represents a much smaller area. Several considerations and limitations affected the selection of stations. First, the stations selected had to be year-round hourly reporting stations for which the observations had been placed on punch cards. Second, the selection had to provide good areal coverage. Third, stations which represented purely local conditions had to be avoided. Finally, the number of stations had to be limited to keep the amount of data down to a level that could be handled with the time and money available.

The 89-station network is too sparse to present a detailed picture of the weather and fire danger. Any region of the country will experience times when weather between stations is quite different from that reported at the stations. For this reason the network is inadequate for determining the fire danger associated with each large fire that occurred. It is considered adequate, however, for representing the regional fire danger associated with synoptic-scale weather patterns.

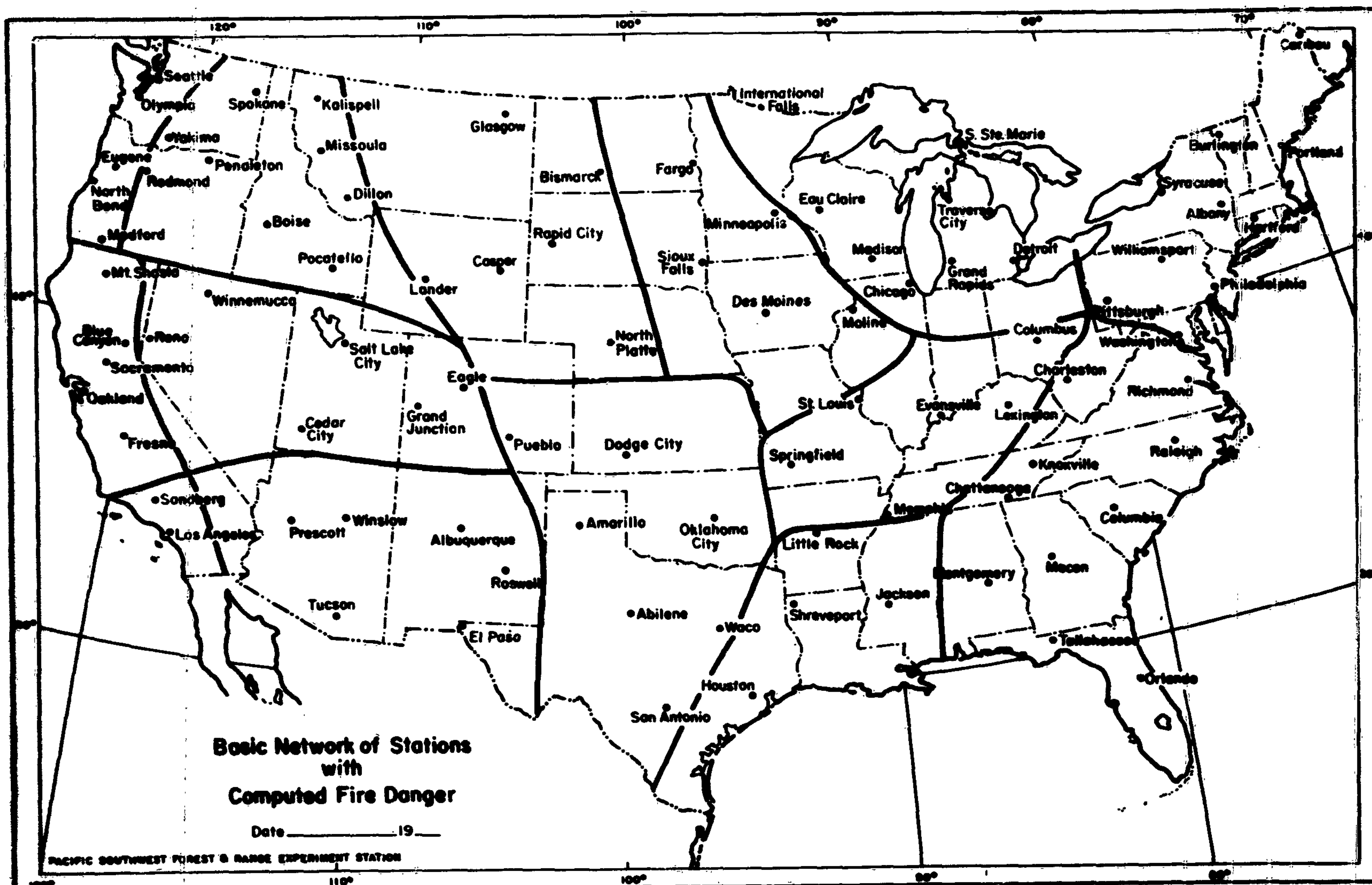

Figure 1. --Basic network of stations for which fire danger indexes were computed.

Weather Data

Once the network of stations was selected, the next step was to generate a basic set of weather data from which fire danger indexes could be computed. The data needed for the 10-year study period included one observation per station per day at about the time of maximum fire danger. Each observation should include those elements needed to compute the indexes, and other elements which might be investigated in individual cases. The elements needed for index computations were:

Temperature------------------------at observation time,
Relative humidity------------------at observation time,
Wind speed-------------------------at observation time,
1/2-inch fuel stick moisture
content--------------------------at observation time, and
24-hour precipitation.

The observation time selected was 1400 LST for most stations although, to obtain observations at the actual time at stations within a region, it was necessary to use the 1300 or 1500 observations at some stations near a time zone boundary.

Wind speed was taken as the average of the speeds at observation time and the two previous hours. The average, we believed, would be more representative of the afternoon wind speed than a single observation.

Since the moisture content of 1/2-inch fuel sticks is not measured at the stations in the network, it was necessary to obtain an estimate from other weather elements.

For this purpose we used a formula developed at the Southern Forest Fire Laboratory[1] which we modified somewhat:

$$FM = e^x - 2.5$$

where FM is the estimated moisture content and

$$x = 3.51682 - 0.02245\,(DBT) + 0.01001\,(DP) + 0.00198\,(RH_{max} + RH_{pm})$$

DBT is the dry-bulb temperature at observation time, DP is the dewpoint temperature at observation time, RH_{max} is the previous maximum relative humidity and RH_{pm} is the relative humidity at observation time. Since precipitation is not in the formula, the moisture content was arbitrarily set at 25.0 whenever the 24-hour precipitation was 0.20 inches or more.

The 24-hour precipitation as of observation time was not available. It was necessary, therefore, to use the 24-hour precipitation as of the previous midnight.

1/ Storey, Theodore G., Estimating the moisture content of fuel moisture indicator sticks from the weather. 1962. (Unpublished report on file at the Southern Forest Fire Laboratory, U.S. Forest Service, Macon, Ga.)

The additional observational elements needed for this and other computations were:

Dewpoint temperature at observation time,
Wind direction at observation time,
Wet-bulb temperature at observation time,
Cloud amount in tenths at observation time, and
Previous maximum humidity.

Since all weather records are now kept at the National Weather Records Center in Asheville, N.C., it was necessary to purchase a copy of the data set from the Center. NWRC selected the proper observations from the decks of hourly cards, and the 24-hour precipitation and maximum humidity from the decks of daily cards, computed the average afternoon wind speed and the fuel-stick moisture content, and placed all of this information on magnetic tapes using a designated format. These tapes were then used as input for 7090 computer which calculated the fire danger indexes of the Wildland Fire Danger Rating System.

Fire Danger Indexes

The Wildland Fire Danger Rating System (fig. 2) uses a multiple index concept designed to provide the most useful information for planning and carrying out prevention, detection, and suppression of wildfires. Separate indexes are computed for each major aspect of fire behaviour, and these indexes can be combined in various ways for specific uses. The system provides indexes for grass areas--where only fine fuels are present, for brush areas--where fine and medium-sized fuels are found, and for timber areas--where fine, medium, and heavy fuels exist. In this study only the timber indexes were computed and used. The timber indexes take into account the moisture contents of the heavy fuels as well as the medium and fine dead fuels, and therefore are sensitive to long dry spells and to cumulative precipitation. Because all these types of fuels are also found in urban areas, the timber indexes should give a reasonable indication of the effects of weather on the behaviour of spreading urban fires.

The moisture content of fine fuels is not measured but is estimated from knowledge of relative humidity and 1/2-inch fuel-stick moisture content. This estimate is used along with temperature to obtain an ignition index, a measure of fire probability due to weather. The fine-fuel moisture and the wind speed yield an index of the rate of spread according to a relationship derived from wind tunnel and field test fires.

The concept used in developing a fire intensity index is that, all else being equal, the intensity will vary with the moisture content of medium and heavy fuels. The drier these fuels are, the more of them will become available for combustion and the more quickly they will be consumed. Fine-fuel moisture content will also affect fire intensity, but its effect is considered in the spread index and is in the same direction as the effect on spread. We feel that this effect is adequately measured by the spread index.

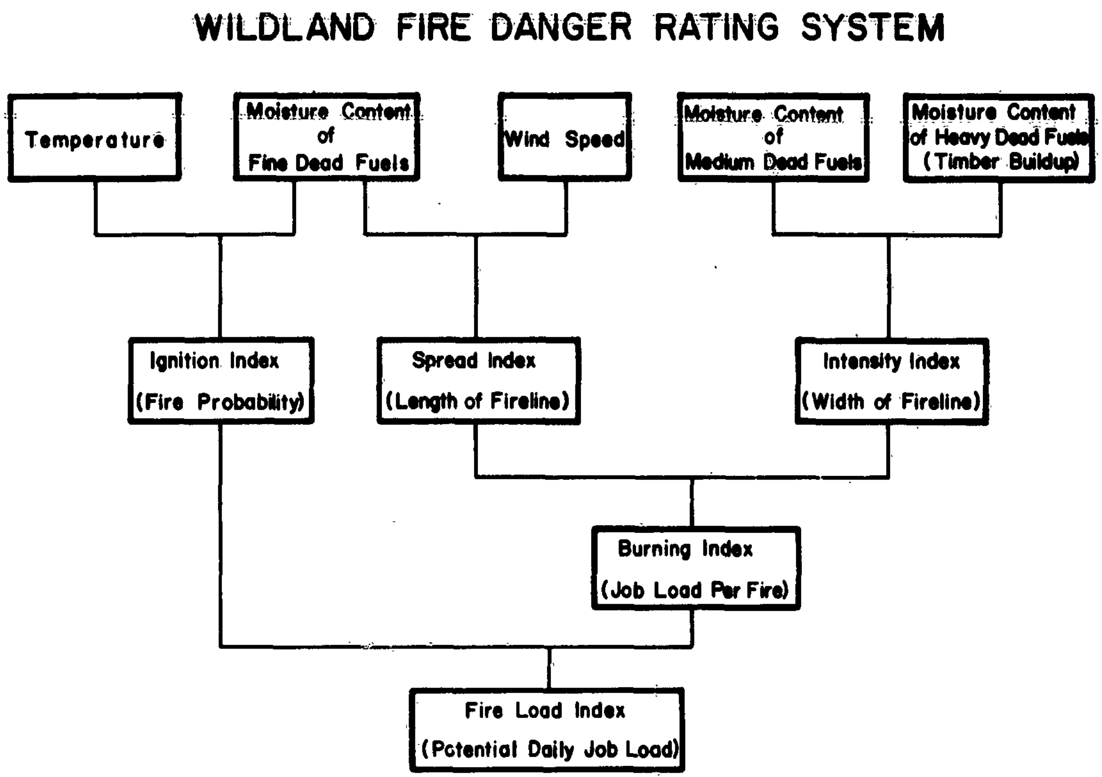

Figure 2. --Structure of the Wildland Fire Danger Rating System for areas with fine, medium, and heavy fuels.

The 1/2-inch fuel stick represents medium-sized dead fuels. An estimate of the moisture content of heavy fuels is obtained through a bookkeeping system. The amount and time-distribution of precipitation and a measure of the daily drying conditions are the parameters used. The estimate of heavy fuel moisture is called the "buildup". Its development was explained by Jensen and Schroeder (1958). Briefly, after a beginning figure for buildup is established[2/] a weighted increment is added to it each day. This increment varies inversely with the 1/2-inch-stick moisture reading, which provides a measure of the daily drying conditions. The idea is that heavy fuels as well as fuels represented directly by the 1/2-inch-stick will dry out more on days with good drying conditions and less on days with poor drying conditions. When precipitation occurs, an increment is subtracted from the buildup. This increment varies with the 24-hour precipitation total and amounts to one unit for each 0.05 inches of precipitation.

2/ For this study the buildup for January 1, 1951 was estimated for each station from the daily precipitation for 1950.

Since drying of fuels is best represented by a logarithmic curve, the buildup index is used on a logarithmic rather than a linear scale. The moisture content of medium fuels and the moisture content of heavy fuels are combined into a fire intensity index, giving equal weight to each.

The ignition, spread, and intensity indexes are the three basic indexes of fire danger. For operational uses the spread and intensity indexes are combined into a burning index which provides a relative measure of the fire control job load per fire, and all three are combined into a fire load index which provides a relative measure of the daily fire load.

The basic weather data and computed indexes were printed out in the form shown in figure 3. The headings (after station, year, month, day, hour) for the variables are as follows:

DWP - dewpoint temperature at observation time
WD - wind direction (in code) at observation time
WS - wind speed at observation time (mph)
DBT - dry-bulb temperature at observation time
WBT - wet-bulb temperature at observation time
RH - relative humidity at observation time
CL - cloud amount at observation time (tenths)
AWS - average wind speed for observation time and the two previous hours
PREC - 24 hr. precipitation ending previous midnight
FSM - estimated fuel stick moisture content (one decimal)
XRH - previous maximum relative humidity
TBU - timber buildup (one decimal) on a scale of 0.0 to 120.0
FFM - estimated fine fuel moisture in percent of dry weight (one decimal)
SPI - spread index
TBI - timber burning index
FII - fire ignition index
FLI - fire load index

Criteria for Critical Periods

The establishment of criteria for the designation of critical fire weather periods nationwide was discussed at a meeting of fire research personnel from different parts of the country before this study was undertaken. The values of the various weather elements which, in combination, produced critical fire weather were considered, and the resulting level of fire load index was determined. It appeared at that time that a fire load index of 22 or higher could be considered critical nationwide. After the fire danger indexes were computed for the nationwide network of stations, however, we found that a single level could not be used for all regions. Some areas would have had only a few days over this value during a year, while others would have had weeks or even months during which every day exceeded that value. It was therefore decided that different levels of fire load index would be used in different regions of the country. The periods of critical fire weather selected could then be considered "critical" only with respect to what is normally experienced in the region.

U. S. FOREST SERVICE — PSW FOREST AND RANGE EXPERIMENT STATION — CD PROJECT NO. 2606

STUDY OF CRITICAL FIRE WEATHER PATTERNS 1951 - 1960

MARK J. SCHROEDER — SEPTEMBER, 1962

TAPE NUMBER 6

PART 1 — DATA AND COMPUTED INDEXES

71 1

STAT	YR	MO	DA	HR	DWP	WC	WS	DBT	WBT	RH	CL	AWS	PREC	FSM	XRH	TBU	FFM	SPI	TII	TBI	FII	FLI
13739	51	1	1	14	20	76	10	39	33	46	4	3	2	147	79	0	80	7	19	2	21	1
13739	51	1	2	14	31	76	11	43	38	62	10	10	0	150	94	1	110	7	19	2	1	0
13739	51	1	3	14	46	56	16	57	51	66	10	16	0	124	87	2	110	12	23	3	1	0
13739	51	1	4	14	38	78	18	52	45	58	4	14	-11	129	88	3	100	13	23	4	6	0
13739	51	1	5	14	25	78	10	45	37	45	5	11	17	133	82	0	80	14	19	3	24	1
13739	51	1	6	14	28	76	10	50	44	63	9	10	0	136	92	1	110	7	19	2	1	0
13739	51	1	7	14	35	32	14	37	36	94	10	14	0	184	99	2	180	0	16	0	0	0
13739	51	1	8	14	14	88	15	28	24	56	6	17	32	250	78	0	120	10	13	2	0	0
13739	51	1	9	14	16	76	15	33	27	49	0	13	0	164	69	1	100	12	19	2	3	0
13739	51	1	10	14	19	66	7	41	34	41	10	9	0	138	88	2	70	12	19	2	32	2
13739	51	1	11	14	30	77	11	39	35	70	10	9	0	165	91	3	130	3	19	1	0	0
13739	51	1	12	14	20	88	12	40	33	44	5	13	3	143	77	0	80	17	19	4	22	1
13739	51	1	13	14	22	16	7	39	33	50	8	8	0	150	74	1	90	8	19	2	12	1
13739	51	1	14	14	33	54	4	33	33	99	10	5	0	199	100	1	180	0	16	0	0	0
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13739	51	1	28	14	35	32	10	36	36	95	10	9	1	189	98	1	180	0	16	0	0	0
13739	51	1	29	14	29	0	0	32	31	89	10	6	14	195	98	0	180	0	16	0	0	0
13739	51	1	30	14	16	11	12	27	24	63	10	16	21	250	86	0	190	6	13	1	0	0
13739	51	1	31	14	17	22	15	19	19	90	10	16	2	237	98	0	180	0	13	0	0	0
13739	51	2	1	14	38	22	4	39	38	98	10	2	96	250	100	0	180	0	13	0	0	0
13739	51	2	2	14	12	78	20	28	24	51	9	19	13	178	63	0	100	20	16	4	3	0
13739	51	2	3	14	7	12	9	22	18	53	10	9	0	196	60	0	100	7	16	2	3	0
13739	51	2	4	14	7	76	9	35	27	30	8	7	0	140	63	1	70	10	19	2	31	2
13739	51	2	5	14	16	18	7	41	33	36	0	6	0	133	82	2	70	10	19	2	32	2

Figure 3. --Copy of the machine print-out of basic weather data and computed indexes.

The frequency distributions of the fire danger indexes and the fine fuel moisture content by months have been computed for each station for the 10-year period of data. Bar graphs showing the distribution of the fire load index by five unit classes, and curves of cumulative frequency by months are included in Appendix A. If these distributions had been available at the time the fire weather periods in each region were selected for study, a more objective method of selection could have been used. Since they were not available, a subjective determination had to be made of the level of fire load index to use. These levels ranged from 17 in the eastern part of the country and the Pacific Northwest to 50 in the Southern Plains and the Southwest.

Listings of the dates of all C, D, and E fires-[3/] were obtained from the National Forests in each region and from the Northeastern states so that the selection of the critical fire periods might be checked. It was not expected that a perfect correlation would be found between the occurrence of large fires and the critical fire weather periods based on the sampling of weather variables. Indeed, in some regions, the correspondence was poor for several reasons:

First, fires must be started, so that periods of high fire danger without large fires could be expected.
Second, effective fire control is not considered.
Third, variations in fire danger must be expected in both time and space. The fire weather at the time and place of a fire may not be the same as that measured in mid-afternoon by the nearest station in the sparse network.
Fourth, the date of the fire given in the fire records is the date of discovery, whereas the fire may have burned its greatest acreage on a subsequent day.
Finally, fuel types are not considered. Large acreages were burned in grassland areas where the fire load index, computed for areas with not only fine, but also medium and heavy fuels, did not indicate critical weather.

The fire records nevertheless afforded a valuable check of the periods of high fire danger selected from the weather records. They gave assurance that no periods during which disastrous fires occurred were overlooked. In some of the western regions where the number of days or periods of high fire danger were so numerous that not all of them could be included in the study, the fire records sometimes helped make selections. Also, in the Northeast region a number of periods were selected for study because of large-fire occurrence even though the fire load indexes did not reach 17.

3/ C fires are 10 to 99 acres in size, D fires, 100 to 299 acres, and E fires, 300 acres or more.

Through this process, then, the periods of critical fire weather for each region were identified for the 10-year study period. We then proceeded to answer the question "What kind of weather patterns produced the critical fire weather?"

METHOD OF DETERMINING AND DESCRIBING SYNOPTIC PATTERNS

The next step was to determine the synoptic weather types associated with these periods. This was done by a study of the surface and upper-air weather maps. The maps used for the 10-year study period were: (a) the series of Northern Hemisphere Weather Maps published by the U. S. Weather Bureau and (b) microfilm copies of the maps prepared by the National Weather Analysis Center.

As the maps were studied, notes were made on the surface and upper-air features which were to help in grouping the cases into similar types, and later in describing the types. For this purpose a classification system was set up for defining the upper-air patterns and the surface anticyclones. The upper-air patterns were defined as meridional, zonal, block, or short-wave train.

The meridional pattern (fig. 4) is one in which the long waves of the belt of westerlies aloft have a large amplitude swinging from quite low latitudes to quite high latitudes and back again. The long waves are slow-moving, and when they have such large amplitude they produce periods of positive temperature anomolies in the areas under the ridges and negative temperature anomolies in the areas under the troughs. There is a large meridional transport of warm air masses from low to high latitudes and of cool air masses from high to low latitudes. Short waves move through the long-wave pattern, usually accompanied by surface cyclones which deepen as they move through the long-wave trough and fill as they move through the long-wave ridge.

In the zonal pattern (fig. 5) the long waves have small amplitude and long wave length. There is little meridional transport of warm or cold air masses. Instead the air masses are steered mostly from west to east. Temperatures in most regions of the country are near normal, although in the Far West where a source of cool air is found off the coast the temperature may run somewhat below normal. Short-wave troughs move through the long-wave pattern, usually accompanied by cyclones at the surface but these cyclones tend to be rather weak.

The blocking pattern (fig. 6) is one in which a High is found north of a Low, both imbedded in a split belt of westerlies. A part of the belt flows north of the High while another part flows south of the Low. These two parts join again to the east of the block. This blocking pattern is a very stable pattern, usually showing little movement for several days. The omega type of block, which is a large amplitude pattern with a closed High in high latitudes, is not included in this classification. Instead, the omega block is grouped with the meridional patterns in this study.

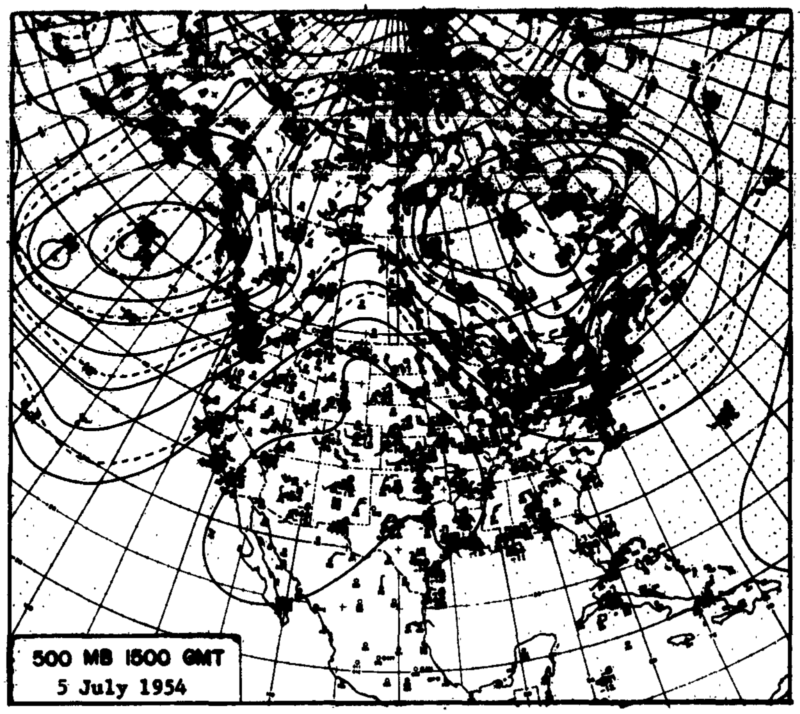


Figure 4. --An example of a meridian pattern aloft as shown on the 500 mb chart.

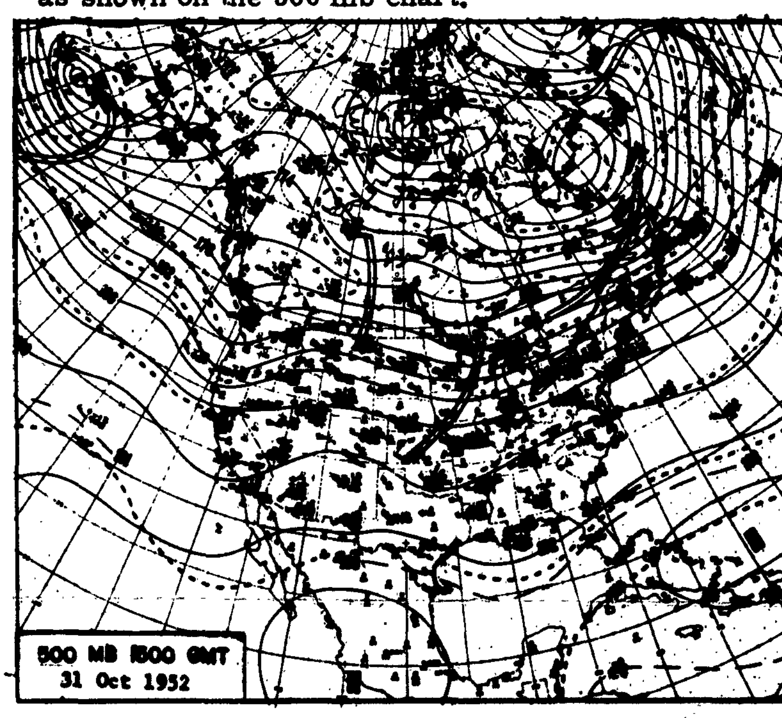


Figure 5. --An example of a zonal pattern aloft as shown on the 500 mb chart.

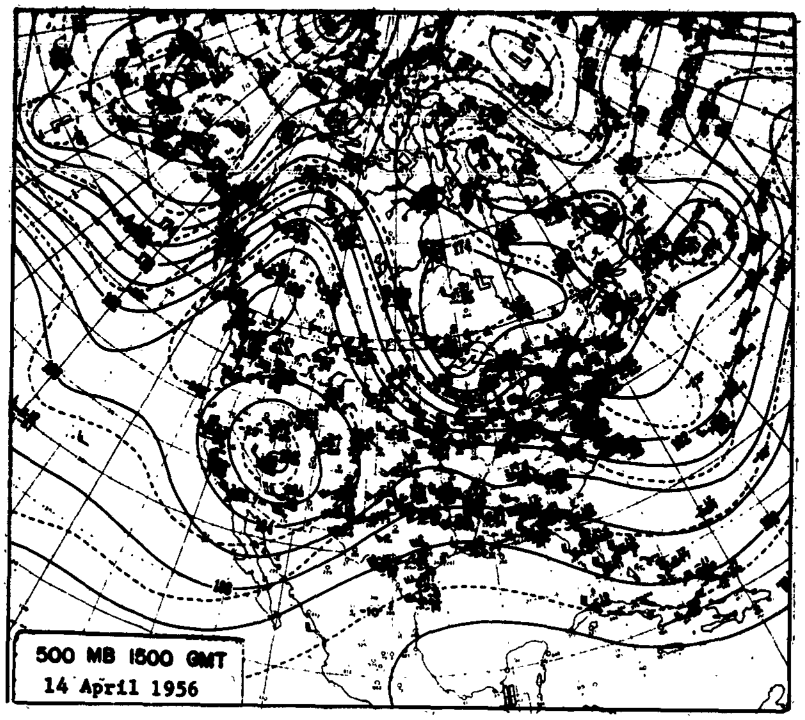


Figure 6. --An example of a blocking pattern aloft as shown on the 500 mb chart.

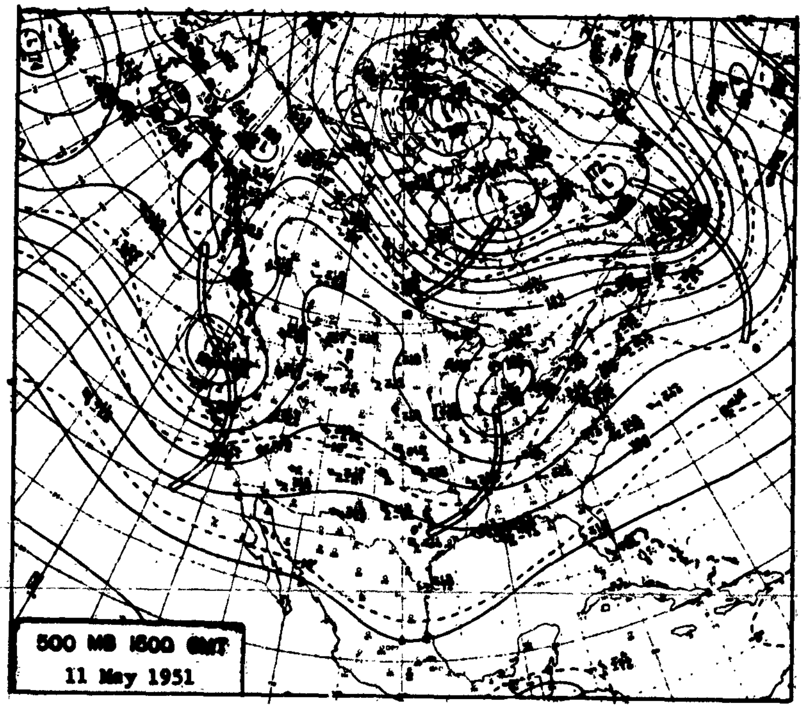


Figure 7. --An example of a short-wave train pattern as shown on the 500 mb chart.

The short-wave train pattern, as used in this study, is one in which there is a succession of short waves so strong that the long-wave pattern is completely obscured within the portion of the belt of westerlies in which the short-wave train is found. In one case the long-wave pattern is obscured completely in a portion of the hemisphere (fig. 7). The short-wave troughs are accompanied at the surface by rather intense cyclones with strong frontal systems. In another case the belt of westerlies is divided. The northern part has a well-defined long-wave pattern, while a more or less independent series of short waves is found in the southern part. In either case the short waves move from west to east fairly rapidly.

Classification of High Pressure Areas

Surface anticyclones were in most cases classified by their origin. The origins were designated as Pacific, northwest Canada, Hudson Bay, or Bermuda, (fig. 8). One surface anticyclone which may originate over the Pacific or northwest Canada, tends to stagnate in the intermountain, or Great Basin; area for some time and become a characteristic feature of the weather maps. This High is classified in this study as a Great Basin High.

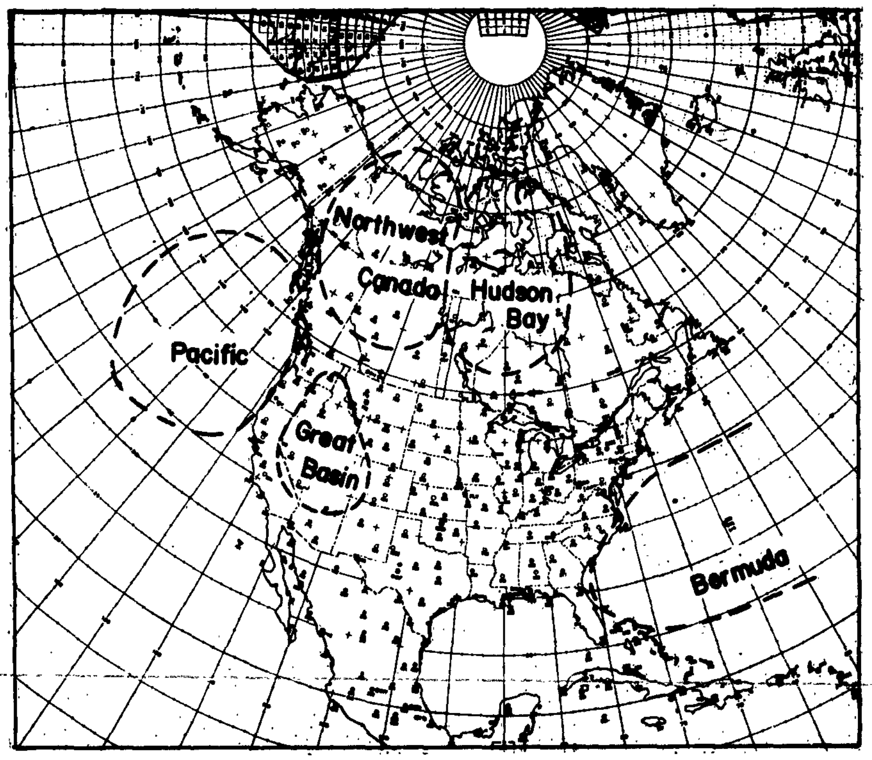


Figure 8.--Designation for origin or location of surface anticyclone.

The notes tabulated for each period of high fire danger include the origin of the anticylones (if an anticyclone was the predominant feature of the type), the initial upper-air pattern at the beginning of the type (when the anticyclone began moving from its source region), the final upper-air pattern, and the portion of the anticyclone in which high fire danger occurred. For the latter, the portions of the High were designated as northern quadrant, post-frontal (the area immediately behind the front moving in advance of the High), southern quadrant, and pre-frontal (the area ahead of the front following the High). In some pre-frontal cases the area of high fire danger was in the warm sector of the cyclone following the High.

Distinction Between Types and Patterns

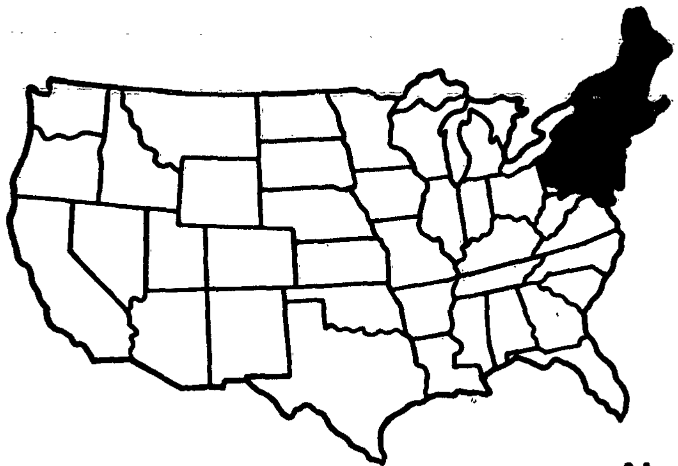
From these notes most of the periods of high fire danger could be classified into a few weather types and the types could be described. Very early in the study it became apparent that in some regions of the country the surface weather pattern was the important feature, whereas in others the upper-air pattern was important. Hereafter the surface weather patterns will be referred to as surface weather types. Usually these types are associated with an anticyclone that develops in a source region and subsequently moves into or through the country. Highest danger is found on the periphery of the anticyclone where the pressure gradient, and therefore the wind speed, is stronger. Descriptions of the weather types begin with the initial movement of the anticyclone out of its source region, carry on through the period when fire danger becomes high, to the time when the fire danger diminishes.

In some regions of the country, particularly the Southwest and the Great Basin, the surface pressure pattern is very flat during periods of high fire danger. The high fire danger appears to be related to the pressure pattern aloft. These upper patterns will be referred to as patterns rather than types. The method of classifying the long-wave patterns aloft has been described previously. The high fire danger associated with these frequently extends over many days and covers a broad area. The particular area that is affected by the pattern depends upon the longitudinal location of the ridge aloft and the latitudinal location of the belt of westerlies or jet stream. Under the ridge the surface temperatures tend to be abnormally high and thus contribute to the high fire danger. Under the belt of westerlies stronger winds are frequently transferred to the surface, particularly in high elevations and mountainous country. This belt also defines the path of short-wave troughs with their attendant strong and shifting winds. The highest fire danger is associated with passage of the short-wave trough.

We now had selected the critical fire weather periods and had studied the synoptic weather maps associated with those periods. The next step was to group them into identifiable patterns and types and to describe their life history.

Regional Fire Weather Patterns and Types

In this section, the synoptic fire weather patterns and types that are important in various parts of the country are discussed region by region. The discussion was not organized by synoptic types because the variations in each type that influenced different regions would have to be discussed repeatedly. A regional arrangement permits anyone interested in a particular region to find in one place discussions of all types which influence his region of interest.



Northeast Region

In the Northeast region the normal level of fire danger, as determined from weather variables, is comparatively low. It was necessary to use fire load indexes of 17 and above to obtain a reasonable number of cases for study of critical periods. In the southern part of this region, a fire load index of 17 occurs about 1 percent of the time during the months of April through September. In the northern part, the 1 percent level for these months runs from 11 at Burlington to 15 at Syracuse. (For more detailed information on the frequency distribution of fire load indexes see Appendix A.)

Periods of high fire danger thus defined usually lasted only 1 day, occasionally 2 days, but rarely 3 days. Several weather types occurred on successive days during the longer periods.

In addition to the periods of high fire danger determined from the fire load indexes, some periods were selected because of the occurrence of large fires in the region, thus recognizing that the fire load indexes may not be representative on occasion because of the place and time of the weather observations upon which they are based. In all, 184 days of high fire danger during the 10-year period were considered in this study, 29 of which were selected from fire records.

High fire danger periods in the Northeast are most frequently associated with an air mass of polar origin moving into the region as Canadian or Pacific Highs (tables 1 and 2). Two other synoptic types associated with high fire danger are the Bermuda High type and the Atlantic Storm.

The area of high fire danger is usually around the periphery of the High where the pressure gradient, and therefore the wind, is stronger. There are indications that the portion of the High where high fire danger occurs usually varies with the track taken by the High.

Table 1.--Number of days with fire load index 17 and above[1] by season and synoptic type, Northeast region, 1951-60

Type	Winter	Spring	Summer	Fall	Total
Canadian High	1	70	33	15	119
Pacific High	0	15	19	5	39
Bermuda High	0	2	12	5	19
Atlantic Storm	1	5	0	1	7
Total	2	92	64	26	184

1/ Except for 29 days which we selected from fire records.

Table 2.--Number of days of high fire danger by fire load index and synoptic type, Northeast region, 1951-60

Type	Maximum Index	Fire load index equal to or greater than--: 1/17	24	30	35	45	55
Canadian High	56	119	27	8	7	3	1
Pacific High	31	39	9	1	0	0	0
Bermuda High	29	19	7	0	0	0	0
Atlantic Storm	20	7	0	0	0	0	0
Total	--	184	43	9	7	3	1

1/ This column includes 29 days selected from fire records.

If the High passes on the north side of the region the high fire danger tends to occur in the post-frontal area, that is, in the forward side of the High. If the High moves through the region, the high fire danger may be either post-frontal or pre-frontal. The pre-frontal area, or warm sector, is on the west or northwest side of the High ahead of the next frontal system. If the High moves across south of the region, the high fire danger area is on the northern side of the High.

Fire danger is not high in the post-frontal area unless the front is dry. Dry frontal passage is more likely to happen with northwesterly rather than southwesterly flow aloft and with the storm track to the north of the region. Although temperatures are not high in the post-frontal area, the relative humidty may be quite low and winds may be strong from the west or northwest. High fire danger in the post-frontal area usually lasts only 1 day and terminates when the center of the surface High passes over the region, thus decreasing the pressure gradient and winds. However, owing to rapid movement of surface systems, a similar type may occur the very next day.

The pre-frontal area may be the area ahead of a cold or occluded front, or it may be the warm sector of a frontal wave. Fire danger becomes high in the case of a warm sector because of the high temperatures and greater instability in this area. Since this area is on the western side of the surface High where moisture is usually being advected from the Gulf of Mexico northward, the high fire danger occurs in the area ahead of the moist air. Once the moist air comes in, the fire danger decreases and is frequently ended by precipitation. Pre-frontal high fire danger may also end with the passage of the cold front if passage is accompanied by either an increase in relative humidity, a decrease in temperature, or a decrease in wind speed.

When the High is south of the region, periods of high fire danger occur with dry troughs moving across the north side of the High. With each trough the pressure gradient increases, producing stronger winds which shift in direction as the trough passes. Fire danger eases when the trough has moved east of the region and winds have decreased.

The Canadian High Type

In the Northeast region this type includes Highs which originate in either the Hudson Bay area or northwest Canada. There appears to be little difference in the resulting fire weather in the Northeast between Highs from these two source regions.

Of the 184 days of high fire danger in the Northeast, 119 days or 65 percent were associated with this fire-weather type (table 2). Of the 119 days, 70 occurred during the spring months, 33 during the summer months, and only 15 during the fall and 1 during the winter. The highest fire load index, 56, occurred with this type. On 27 days the fire load index was 24 or higher.

The Canadian High type can affect the Northeast region under either meridional or zonal flow aloft. The most predominant pattern aloft is one in which the flow is initially meridional--with a large-amplitude ridge over central or western Canada--and later becomes more zonal, particularly over eastern North America.

The Canadian High moves southward or southeastward into the central United States under the influence of the northerly flow on the east side of the meridional ridge. One to two days before high fire danger in the Northeast the flow aloft flattens and becomes more zonal. The surface High then moves eastward toward the mid-Atlantic states and becomes elongated east-west.

The Northeast region is on the northern side of the High on the days of high fire danger. Surface winds as well as winds aloft are westerly. The air mass is dry and Gulf moisture is cut off by the westward extension of the surface High. Isobars on the north side of the surface High become packed and winds become stronger as troughs or low pressure areas pass by to the north. The warm sectors of open waves are particularly critical areas.

An example of this type is shown by the surface and 500 mb charts in figure 9 for the period May 1-10, 1957. May 8 and 9 were the critical days. On May 8, Portland, Me., had a fire load index of 35; Hartford, Conn., 22; Albany, N.Y., 26; Williamsport, Pa., 20; Philadelphia, Pa, 17; Syracuse, N.Y., 17; and Caribou, Me., 17. On May 9, Portland, Me., had 37; Albany, N.Y., 22; Hartford, Conn., 19; and Williamsport and Philadelphia, Pa., 17. Fire danger ended in this case on May 10 with a frontal passage from the northwest. In some cases a front approaches the region from the west and the pre-frontal area on the west side of the High is a critical area. In either case the fire danger lowers with the frontal passage.

The flow aloft in this example changed from meridional to a pattern with a High-Low block near the West Coast and zonal flow from mid-continent eastward. In other cases the flow may become zonal all across the continent.

Although in the case just described the area of high fire danger was in the northern or western quadrants of the High, there are cases under meridional flow aloft where the eastern or post-frontal area of the High also experiences high fire danger. This happens when a Low, both aloft and at the surface, deepens in the vicinity of Newfoundland. It becomes quasi-stationary and may even move slightly westward. The flow aloft in this case has a very large amplitude with the ridge extending to quite high latitudes. Frequently this large amplitude results when a deep trough moves onto the Pacific coast.

The center of the Canadian High may move from Canada into the United States, or it may remain over Hudson Bay under the ridge aloft but with a ridge extension of the surface High penetrating southward into the United States. The combination of a deepening Low over Newfoundland and a High or ridge west or southwest of the Northeast region results in a strengthening of the pressure gradient and strong northwest winds. This wind flow pulls down dry air from the east side of the Canadian High. The fire danger becomes lower when the pressure gradient weakens.

Figure 10 shows a case where the High moved from Canada into the southeastern states while Lows both at the surface and aloft deepened in the vicinity of Newfoundland. Note that both the surface isobars and the 500 mb contours are closely packed and oriented northwest-southeast. On May 8, 1951, Philadelphia, Pa., had a fire load index of 27, Williamsport, Pa., had 17, and a large fire occurred in Pennsylvania.

Figure 11 shows a case where the center of the High remained over Hudson Bay during the period of high fire danger, although it subsequently moved southward into the United States and caused another period of high fire danger illustrated in figure 10. The Northeast, on the day of high danger, May 2, 1951, was in the post-frontal area between the Low over Newfoundland and the southward ridge extension from the High over Hudson Bay. Philadelphia, Pa., had a fire load index of 45; Hartford, Conn., 31; Portland, Me., 24; and Williamsport, Pa., 24. The fire danger lessened temporarily when the Low over Newfoundland moved eastward and relaxed the gradient.

As was mentioned earlier, the Canadian High type can also occur with a rather small amplitude, or even zonal, pattern aloft. The flat ridge is located over western North America and the shallow trough is near the east coast. The belt of westerlies is rather far north in a zonal pattern during all but the winter season. The surface High moves from northwest Canada southeastward or east-southeastward under this flow and usually passes through the Northeast region. The cold front preceding the High usually trails from a low pressure area moving eastward across southern or central Canada.

The high fire danger occurs immediately after the frontal passage when dry air from the eastern quadrant of the High moves into the region. Temperatures with this type are not high, but this is offset by low humidities and strong winds. Anti-cyclonically curved isobars which diverge downstream are conducive to subsidence in the post-frontal area and frequently occur with this type. The period of high fire danger usually lasts only one day, but since movement is quite rapid under zonal flow, a similar type may occur the very next day. Fire danger decreases when the center of the High passes over the region.

Figure 12 shows a High from northwest Canada moving through the Northeast region under zonal flow. The day of high fire danger associated with this High was June 19, 1952, when Washington, D.C., had a fire load index of 21 and Philadelphia, Pa., had 20.

The Pacific High Type

In the Pacific High type the high pressure area that eventually affects the Northeast region is a "break-off" which has separated from the semi-permanent east Pacific high pressure cell. The air mass is a maritime polar (mP) air mass at least in the lower layers. It enters the Pacific coast usually from northern California to British Columbia. In the summer season particularly, the moist layer is shallow and a very dry air mass is superposed. Much of the lower moist layer is blocked from moving inland by the Cascades. Such moisture as does cross the Cascades is further depleted in the course of its eastward trajectory as it crosses the Rockies. Then in descending the eastern slopes of the Rockies, the air mass is warmed adiabatically and its relative humidity decreases. By the time the mP air mass has reached the Northeast region it is mild and quite dry.

To reach the Northeast region, a Pacific High must be steered by zonal flow aloft. Occasionally the pattern aloft has some amplitude, but in any case it is considerably flatter than the meridional pattern associated with most Canadian Highs. The pattern aloft may remain zonal throughout the life history of the type or may become more meridional in the latter stage.

A total of 39 days of high fire danger, 21 percent of the total, occurred with the Pacific High type. Of these, 15 were during the spring months, 19 in the summer, and 5 in the fall. The highest fire load index was 31. Nine of the 39 days had 24 or higher.

As with the Canadian High type, the high pressure area may pass through or south of the Northeast region. If it passes through the region, high fire danger usually occurs either in the post-frontal area or in both the post-frontal and pre-frontal areas. The case of June 15, 1952 (fig. 13) illustrates this type. The belt of westerlies had quite small amplitude from beginning to end of the type and was located across the northern states and southern Canada.

The High entered the West Coast on June 15, 3 days before it affected the Northeast, and moved steadily eastward under the zonal flow aloft. On June 18 in the post-frontal area, Washington, D.C., had a fire load index of 29, Williamsport, Pa., 26; and Philadelphia, Pa., 20. New Jersey had two large fires.

If the Pacific High passes to the south of the Northeast region, high fire danger tends to occur in the pre-frontal area on the western or northwestern side of the High. The belt of westerlies either is located at a lower latitude or has somewhat more amplitude than in the case described above. The location of the belt of westerlies at a lower latitude is more typical of the cool months and the greater amplitude more typical of the summer season.

The period March 2-6, 1956 (fig. 14) illustrates a spring case. The flow aloft was strong and at a rather low latitude. A "break-off" from the east Pacific High entered the western states on March 2, three days before high fire danger in the Northeast. It moved eastward across the country under the strong flow aloft. This Pacific air mass dried out while crossing the Rockies, and was able to acquire very little moisture east of the Rockies because of its rapid movement and the fact that Gulf moisture was cut off. High fire danger occurred in the pre-frontal area on March 5. The fire load index for Washington, D.C., on this day was 24. The fire danger decreased on the following day when the front passed.

A case illustrating the summer situation is shown in figure 15. Only the maps for the day of high fire danger, July 31, 1954, are shown. The past daily positions of the surface High are shown on the surface map. The High entered the Pacific Northwest on July 22 and moved quickly to the Lake States. Then it drifted southeastward and became quasi-stationary over the eastern states. High fire danger occurred in the pre-frontal area on July 31. Washington, D.C. had a fire load index of 27, Philadelphia, Pa., 29, and Williamsport, Pa., 18. The fire danger lowered the following day when the front passed the region.

In its later stages this type strongly resembles the summertime Bermuda High type. In fact, the Pacific High is eventually absorbed into the Bermuda High. High temperatures and low humidities are major contributors to the high fire danger. The increase in surface winds, as a Low passes to the north or a cold front approaches, is a secondary factor.

Occasionally the zonal flow associated with the movement of a Pacific High across the country becomes meridional as a Low deepens in the vicinity of Newfoundland or Labrador. This deepening results in an increase in pressure gradient and wind speed between the Low and the Pacific High which is located over the eastern states. This will produce an area of high fire danger on the north and northeast side of the High.

The Bermuda High Type

The Bermuda High type is primarily a summer situation and is the typical drought pattern for the eastern part of the country. With this type the subtropical Bermuda High, normally located over the Atlantic Ocean, has a westward extension well into the United States. This high pressure area effectively cuts off the northward flow of moist air from the Gulf of Mexico. Such moisture as is able to penetrate the area is shunted far to the west. Temperatures are unseasonably warm.

The flow pattern aloft with the Bermuda High type is quite zonal. The belt of westerlies is far north, usually over northern United States or southern Canada. The long-wave ridge aloft is situated over central or eastern United States and may have one or two closed contours. The surface High and the upper ridge tend to remain nearly stationary for some time.

Short-wave troughs aloft move across the continent near the Canadian border and are associated with weak Lows at the surface which usually move through southern Canada. High fire danger occurs as the isobars become packed on the north side of the Bermuda High with the passage of each trough. Wind directions at the surface and aloft are in phase.

The contributing factors to the high fire danger are, first, the high temperatures resulting from subsidence and clear skies in a stagnant air mass, and second, the increased wind speed occurring with the passage of each trough.

The fire danger may decrease temporarily after the trough has passed and the winds become lighter. If a cold front passes the region and brings in a cooler air mass, more lasting relief is experienced. The high fire danger period may also be brought to an end by the advection of moisture into the region if the pattern changes and permits entry of Gulf moisture.

During the period of study there were 19 days, or 10 percent of the total, of high fire danger associated with a Bermuda High type. Two of these occurred during the spring season, 12 during the summer, and 5 during the fall. The highest fire load index was 29. Seven days were 24 or higher.

The period August 25-31, 1953 is an example of the Bermuda High type (fig. 16). The Bermuda High at the surface and the pattern aloft changed little during most of the period. Temperatures were in the 90's in much of the eastern part of the country. The significant feature was the passage of a short-wave trough aloft, and associated surface system, eastward along the Canadian border. High fire danger occurred on the north side of the Bermuda High on August 30 when the wind speeds increased. The fire danger lowered on August 31 when winds decreased again.

The Atlantic Storm Type

The Atlantic Storm type does not occur frequently but, nevertheless, is worthy of mention. High fire danger sometimes is found in rather limited areas which are beyond the rain and cloud shield of an intense Atlantic storm but are still affected by its strong winds. The Atlantic storm may be either a tropical storm which is moving northeastward parallel to the coast, or an extra-tropical storm. The latter may be a storm of Gulf origin which crosses Florida and then moves northeastward, one which forms in the southeastern states and moves off the coast and then northeastward, or it may be a Cape Hatteras storm moving northeastward. The land area with high fire danger from these storms usually experiences northeasterly surface winds and air which has a land trajectory.

Only 7 days of high fire danger with this type were found in the Northeast region. This was 4 percent of the total number of days. The fire load indexes ranged from 17 to 20. No example of this type is shown here although one is shown in the section on the Southeast region.

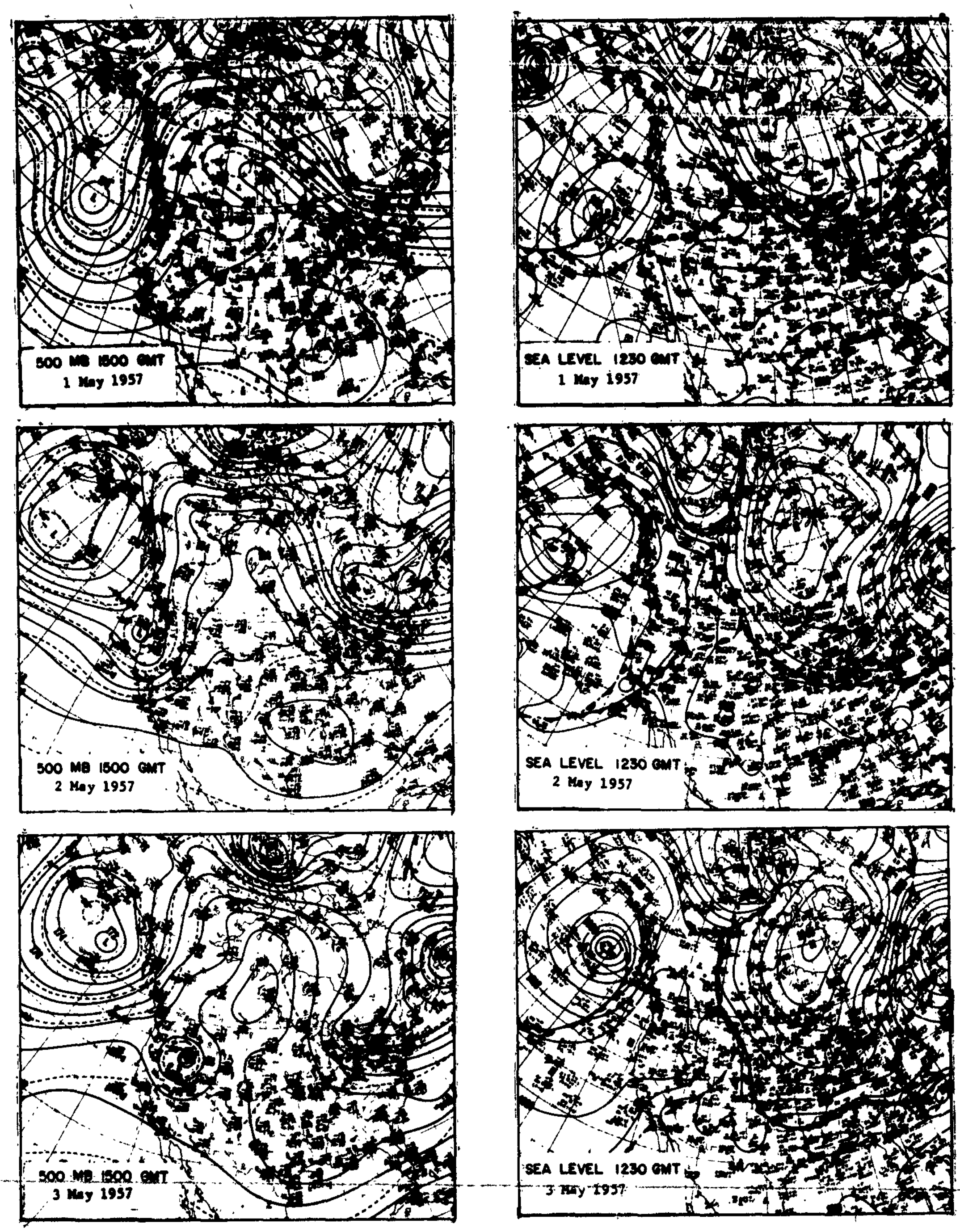


Figure 9. --Surface and 500 mb charts, May 1-10, 1957. Days of critical fire weather in the Northeast were May 8 and 9. Fire danger lowered with frontal passage May 10.

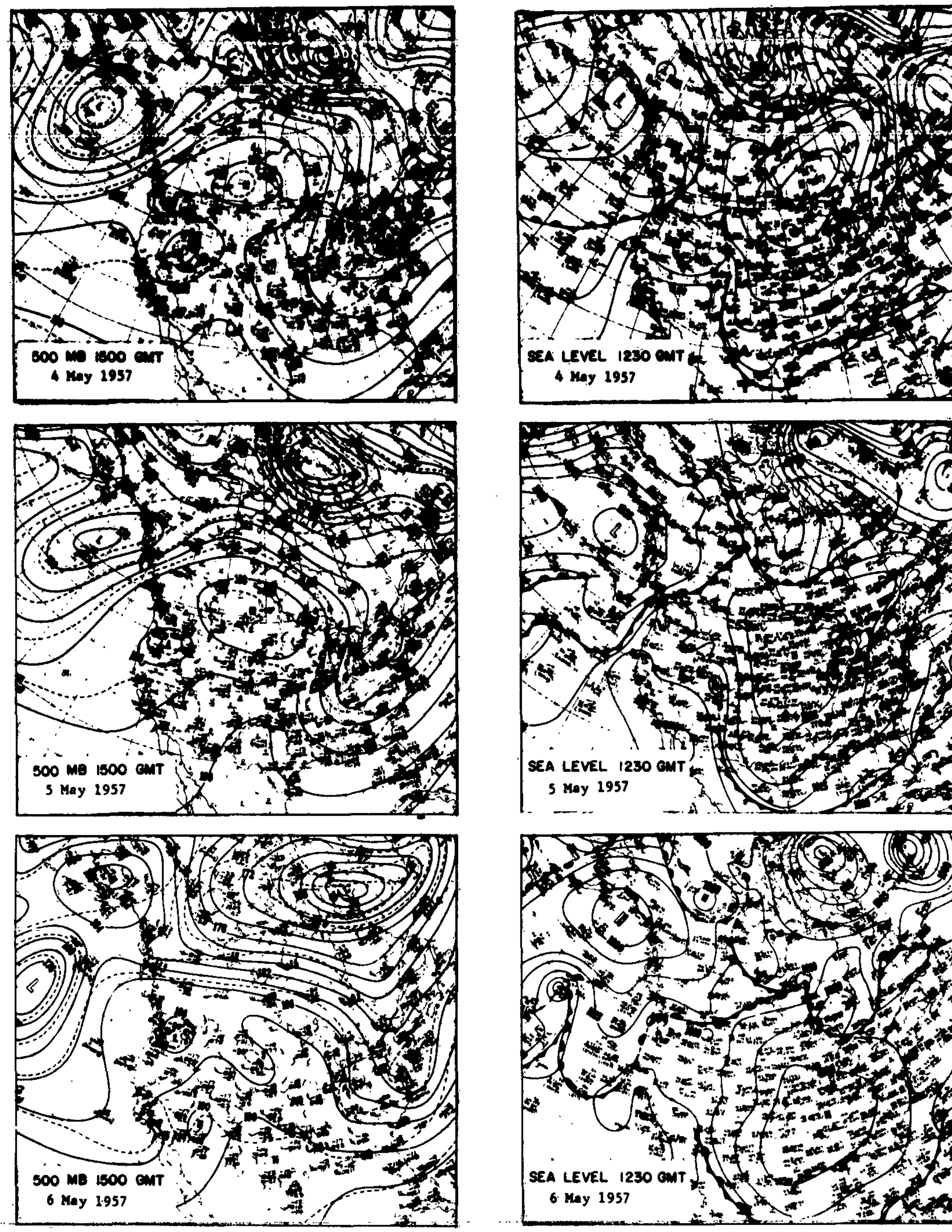
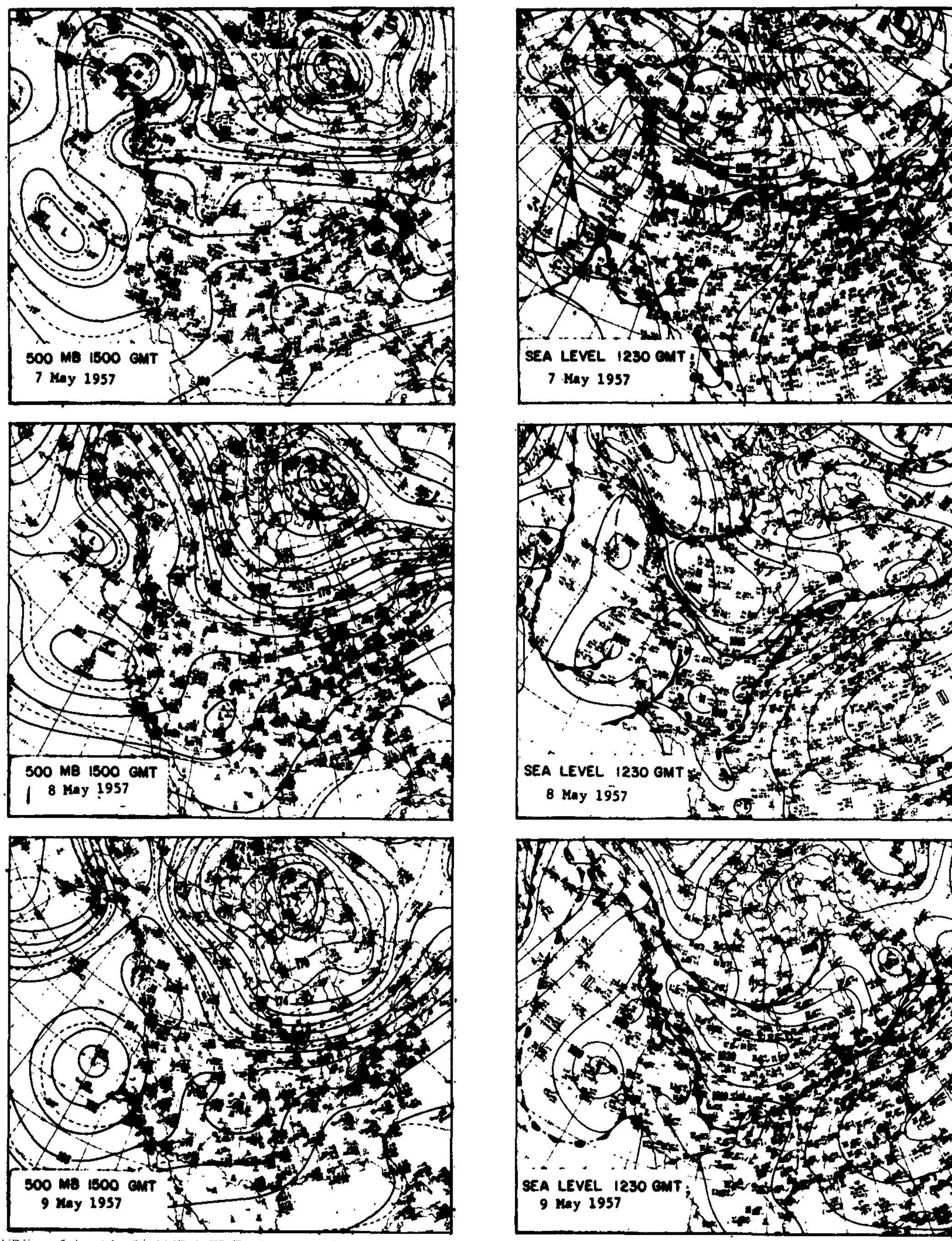


Figure 9. --Continued.



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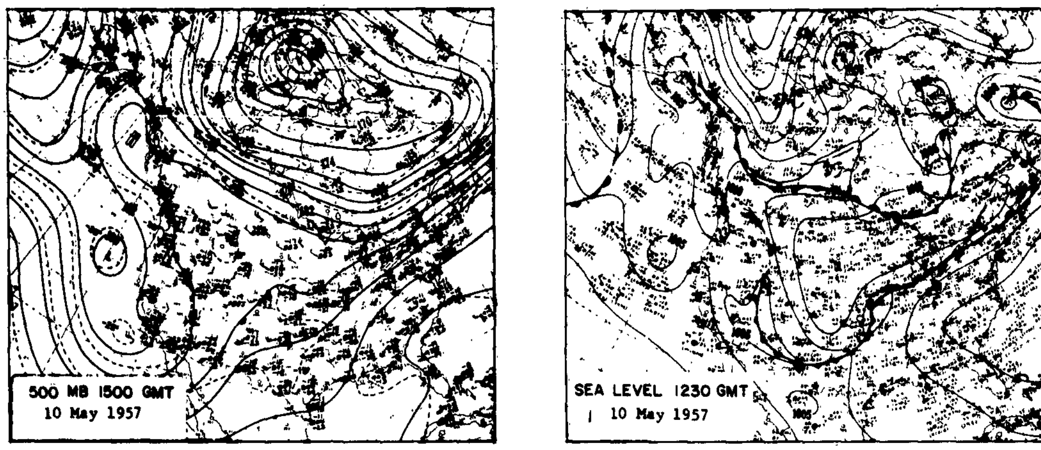

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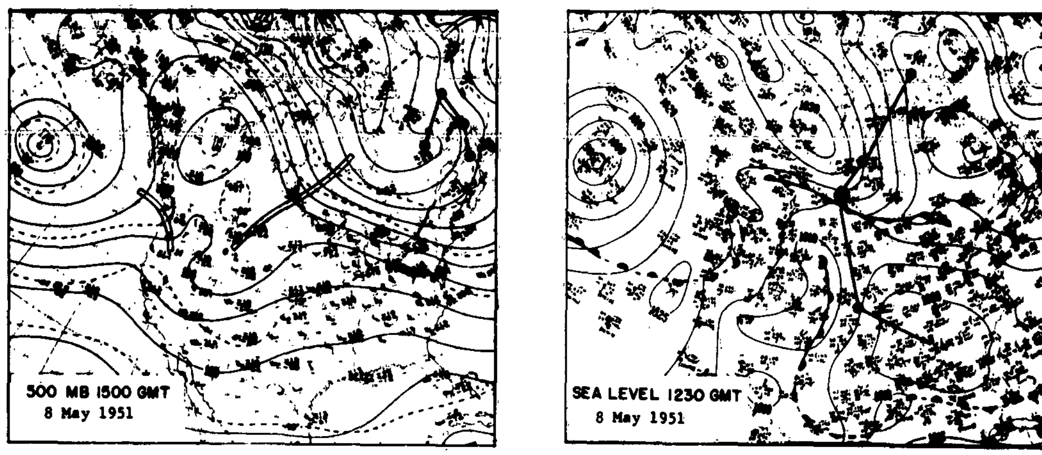


Figure 10. --Surface and 500 mb charts, May 8, 1951. Surface chart shows past daily positions of the surface High; 500 mb chart shows past daily positions of the Newfoundland Low.

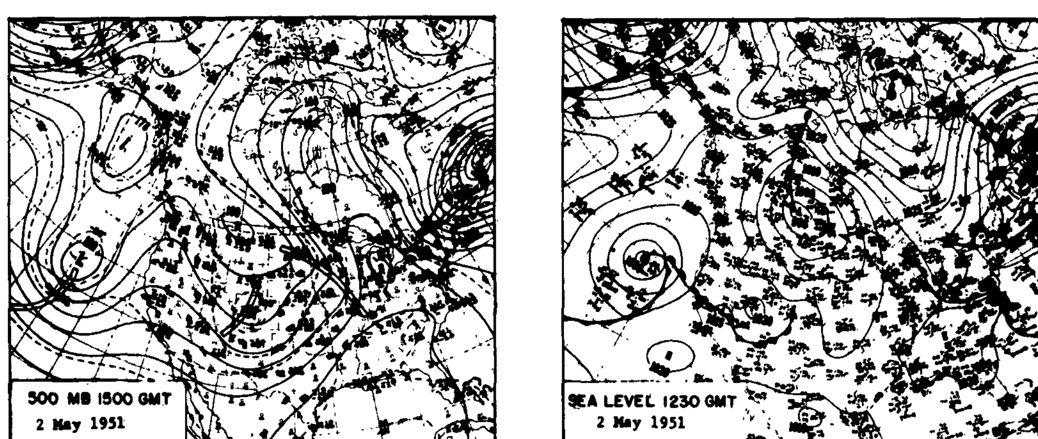


Figure 11. --Surface and 500 mb charts, May 2, 1951. The center of the surface High was nearly stationary north of Hudson Bay and beneath the ridge aloft for several previous days.

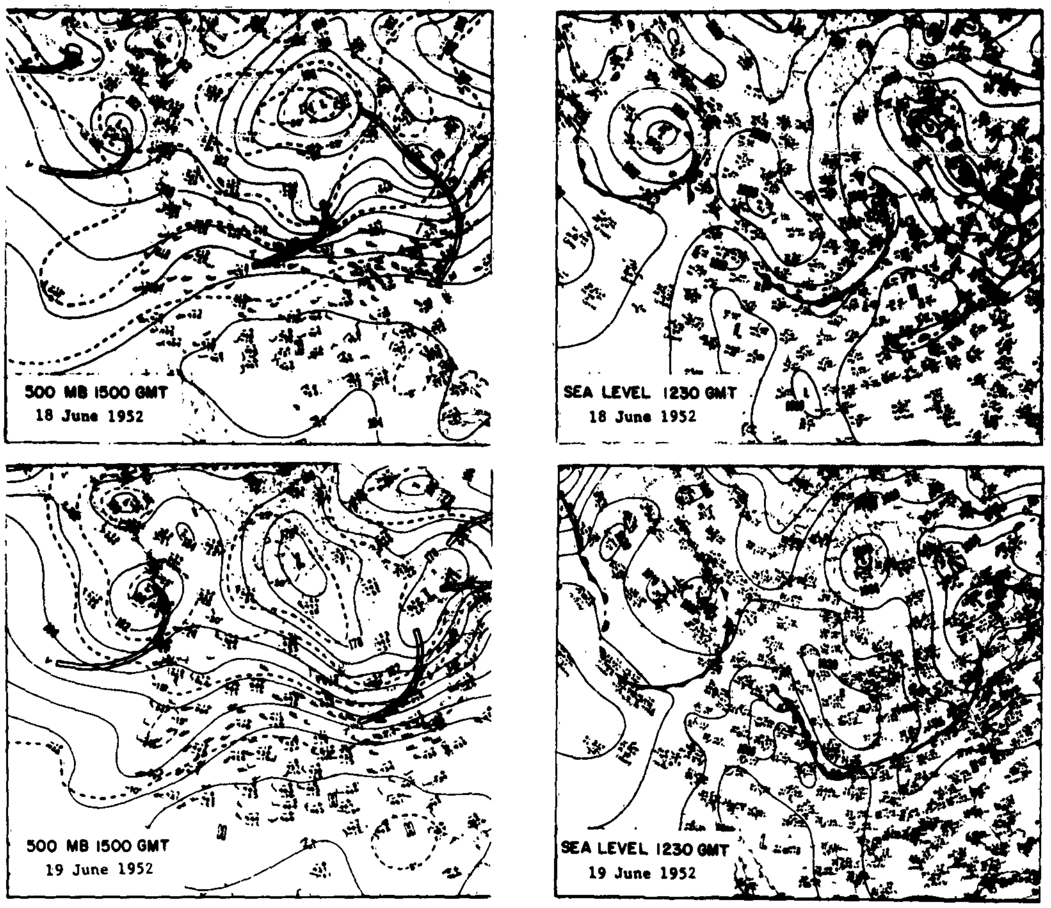


Figure 12.--Surface and 500 mb charts, June 18-19, 1952. The cold front passed the region during the forenoon of June 19.

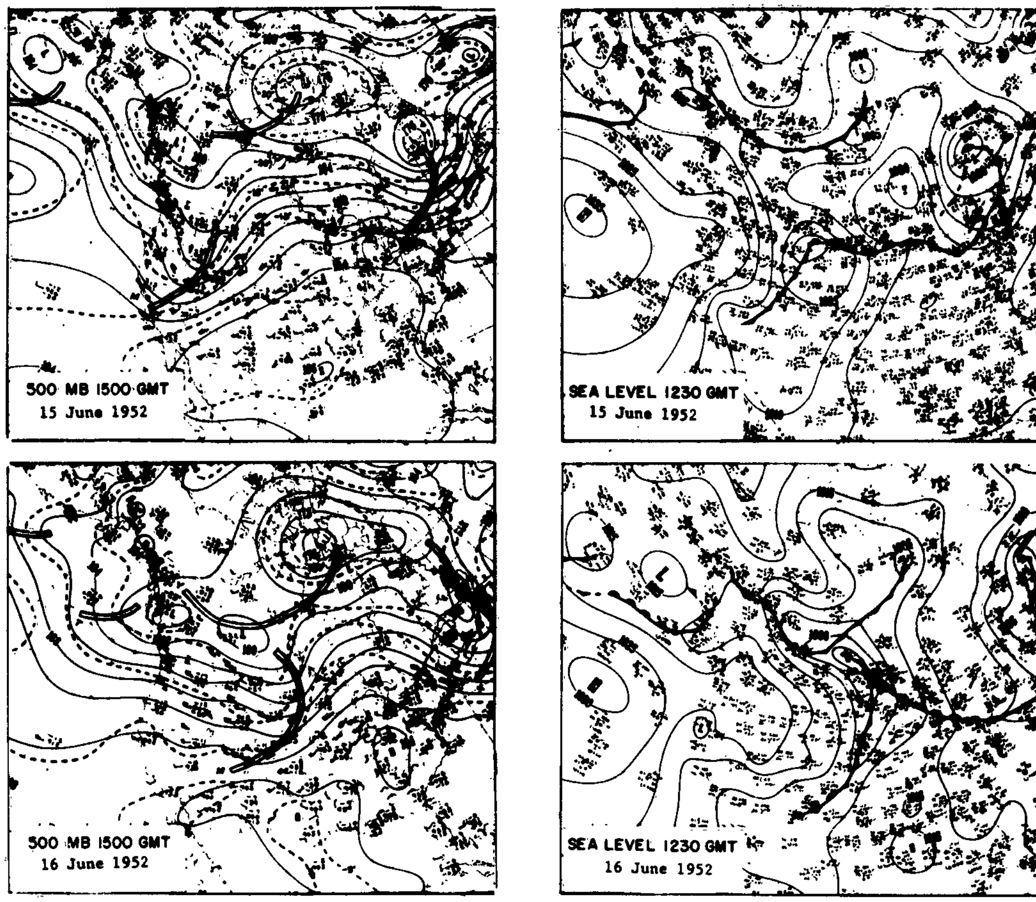


Figure 13.--Surface and 500 mb charts, June 15-18, 1952. High fire danger occurred in the post-frontal area on June 18. On June 19 high fire danger occurred again but was due to a Canadian High which followed the Pacific High.

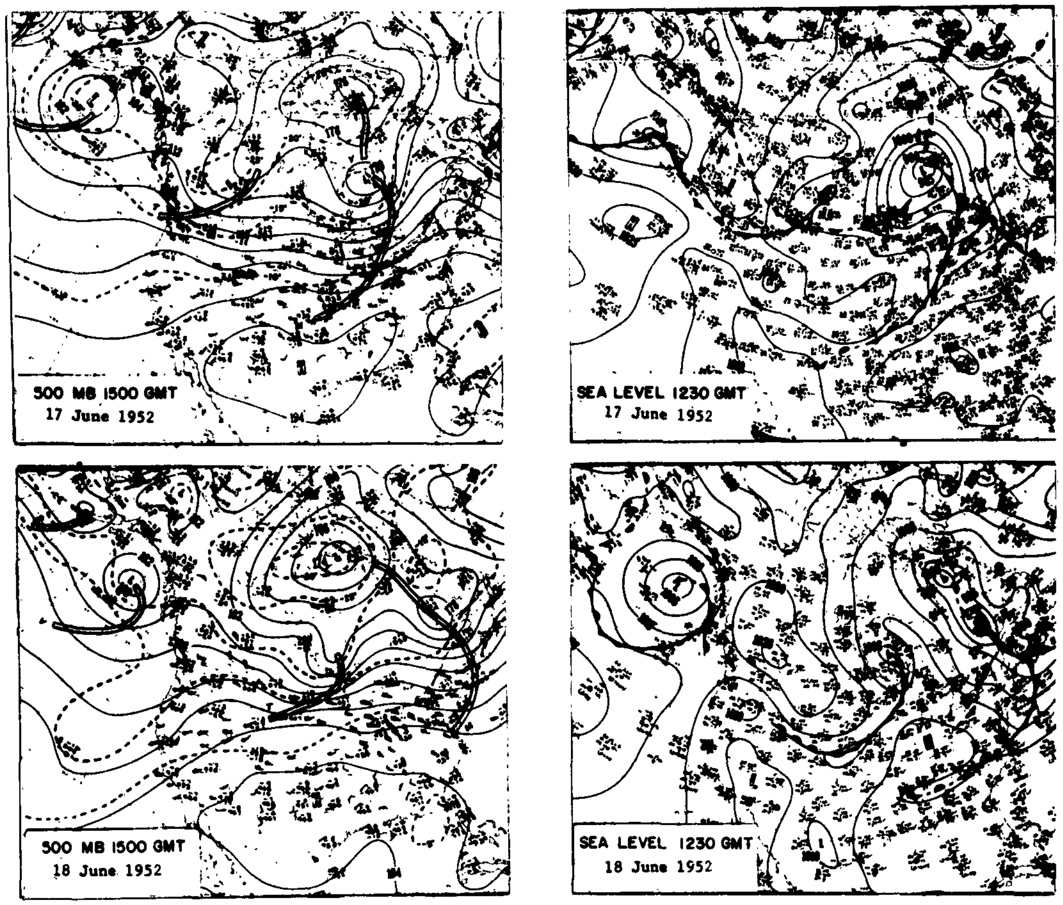


Figure 13. --Continued.

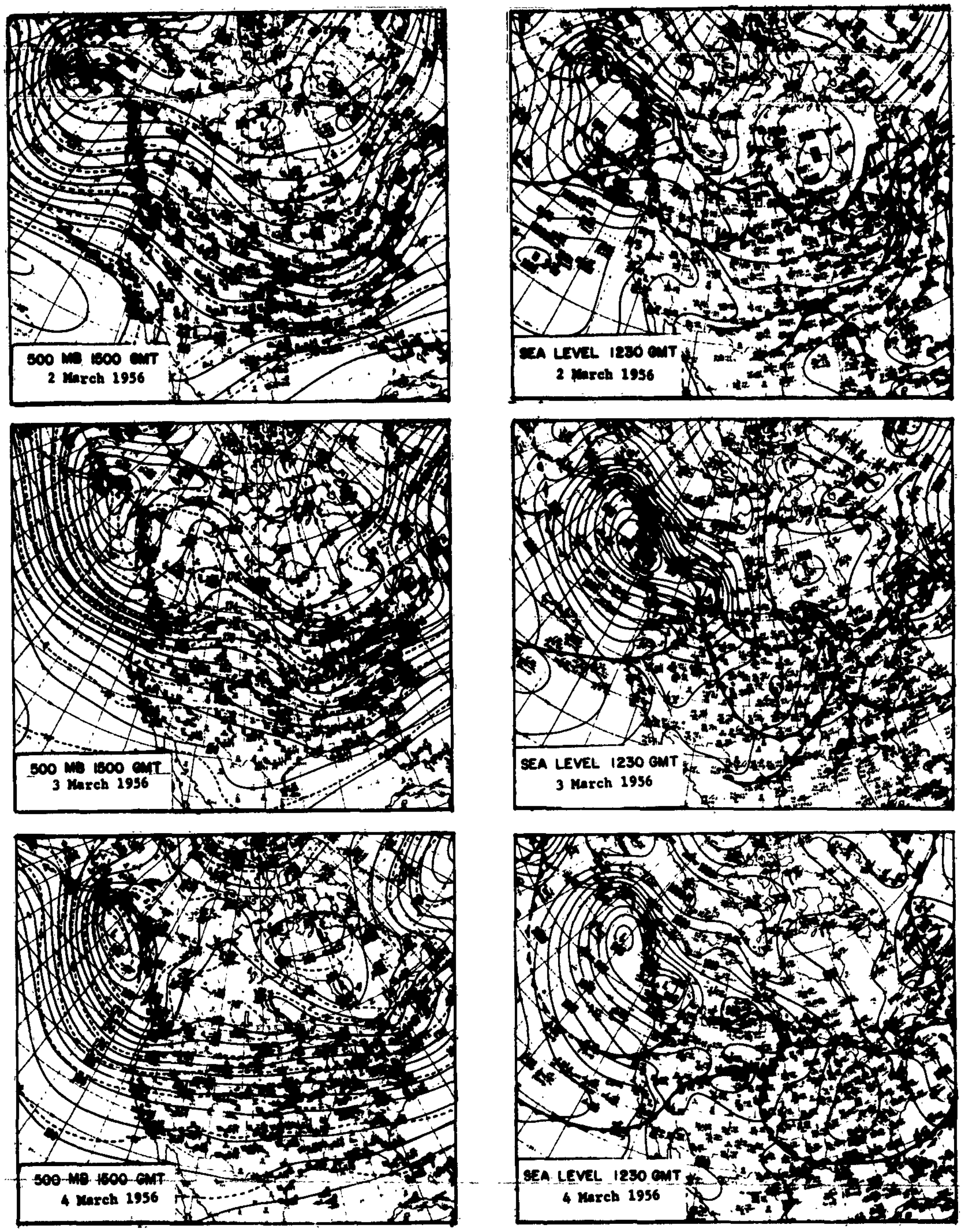
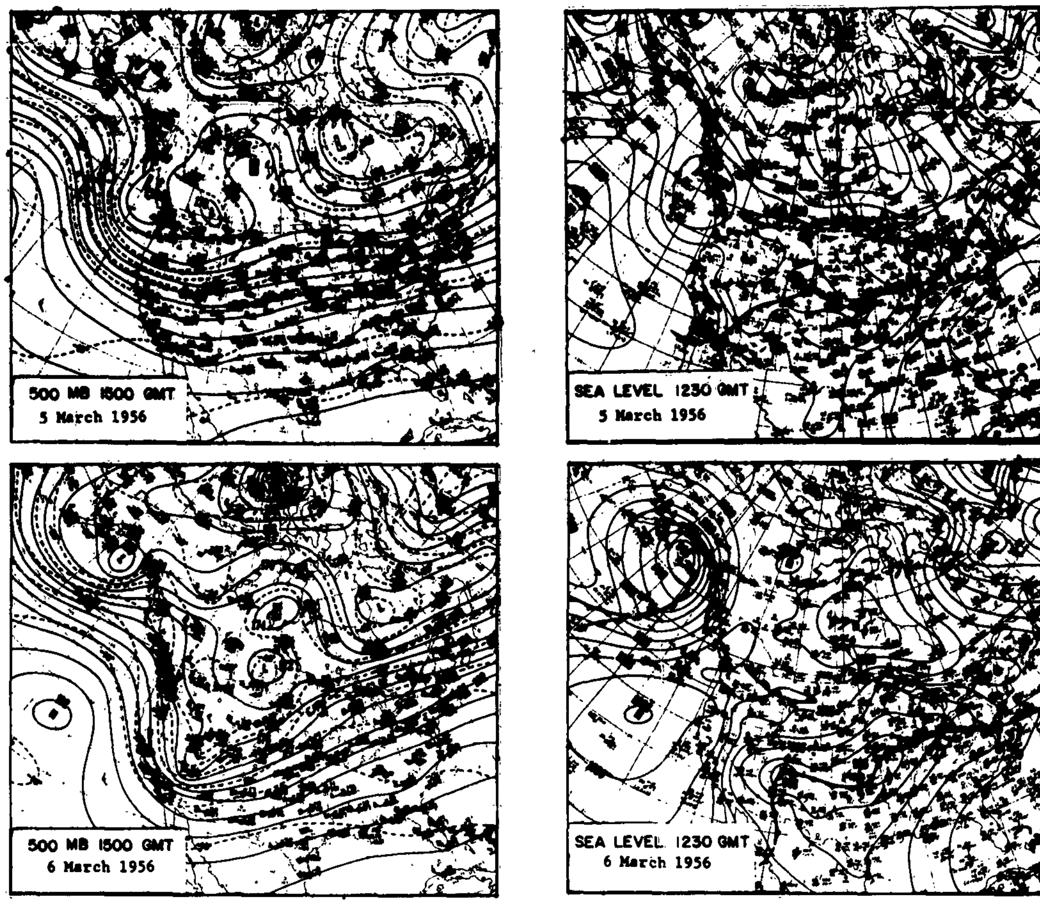


Figure 14.--Surface and 500 mb charts, March 2-6, 1956. High fire danger occurred in the pre-frontal area on March 5.



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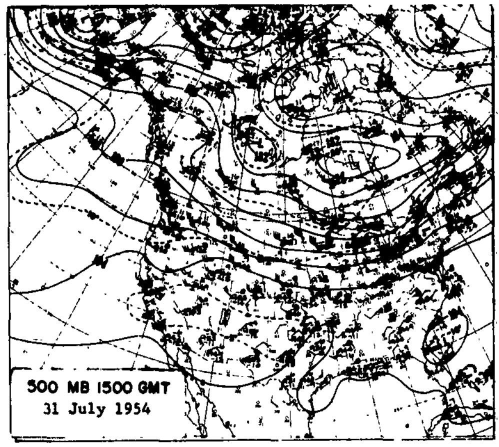


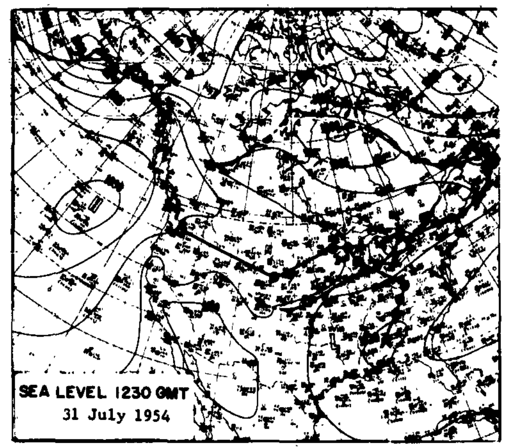


Figure 15.--Surface and 500 mb charts, July 31, 1954. The daily positions of the Pacific High beginning July 22 as shown on the surface map.

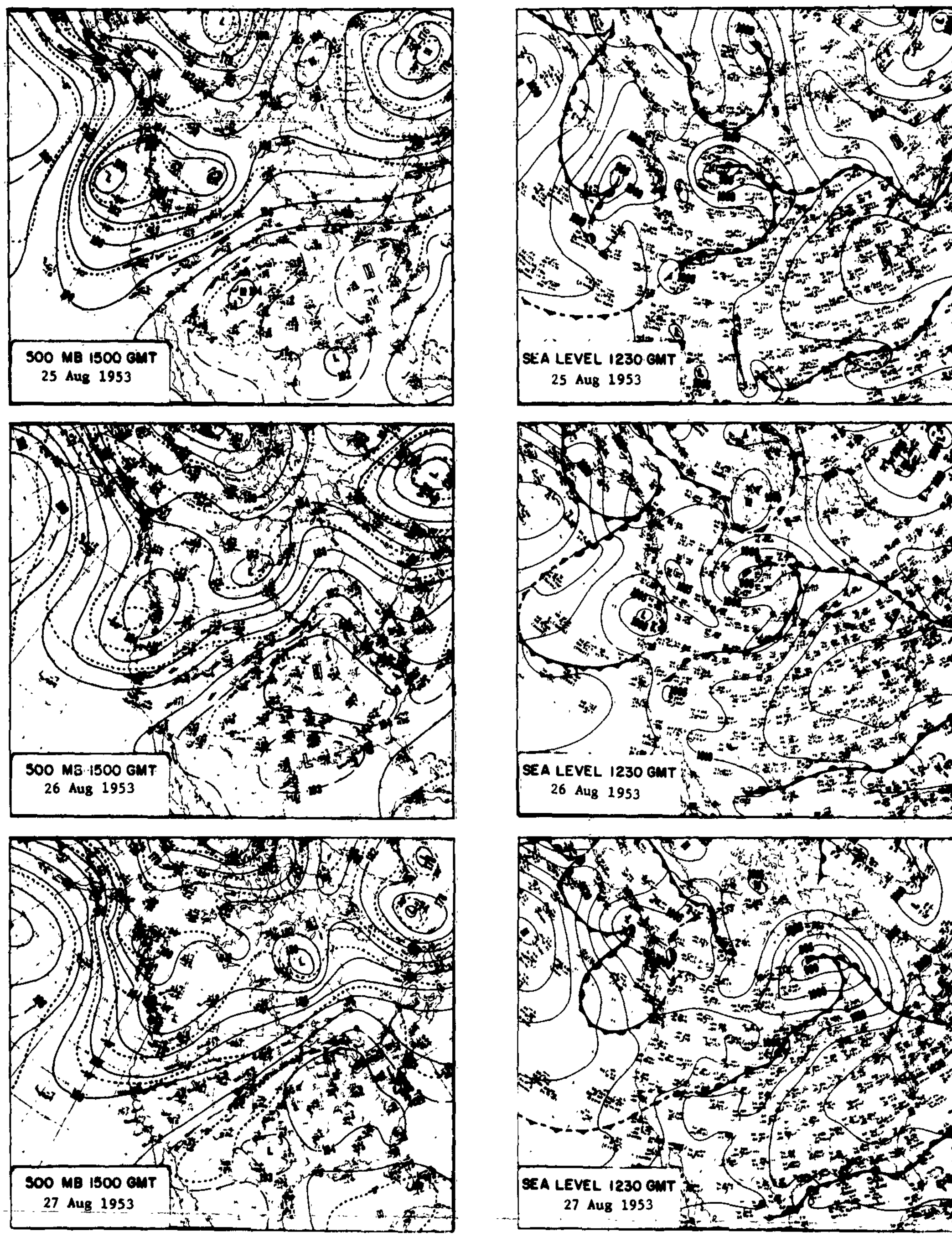


Figure 16.--Surface and 500 mb charts, August 25-31, 1953. High fire danger occurred on the north side of the Bermuda High on August 30.

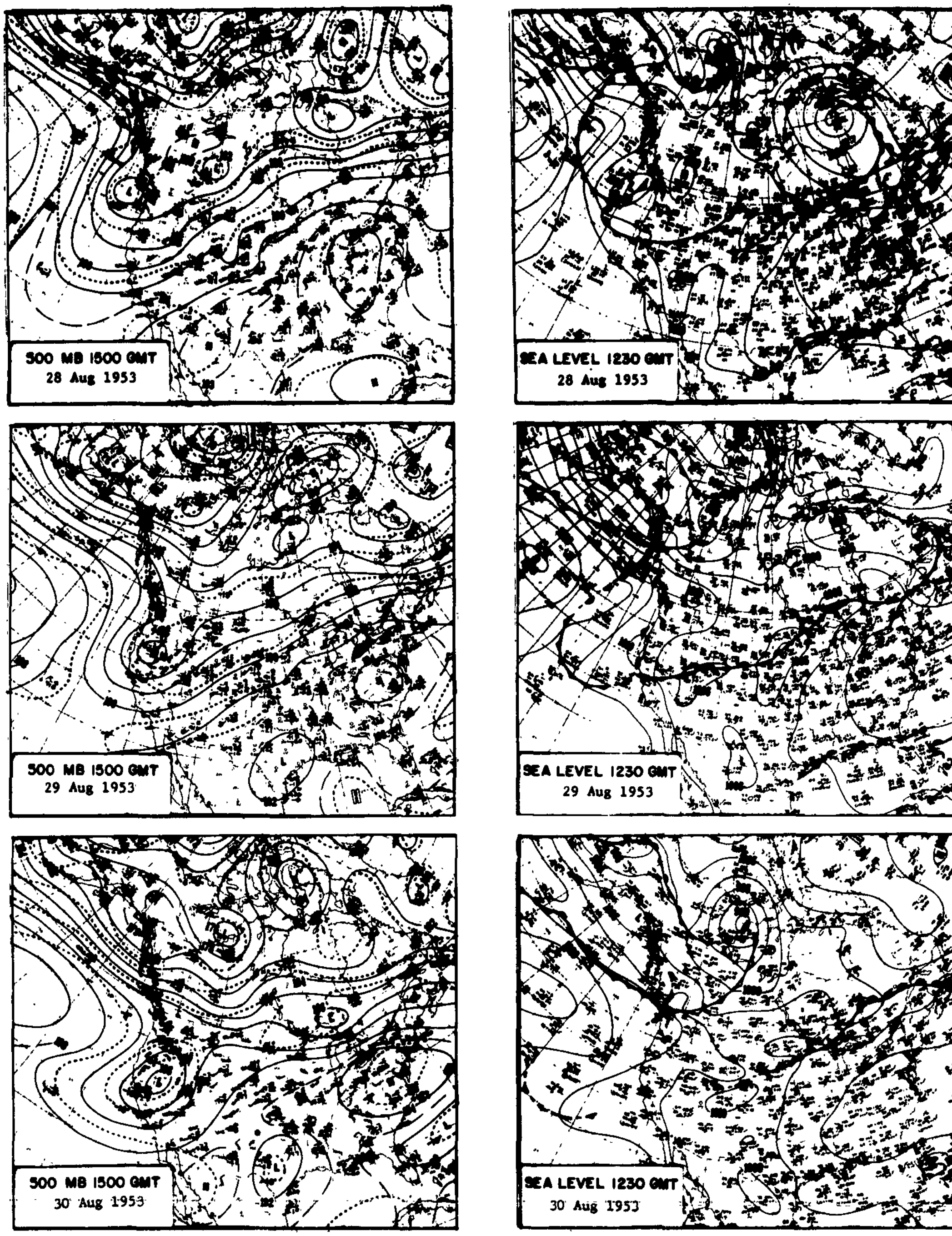


Figure 16. --Continued.

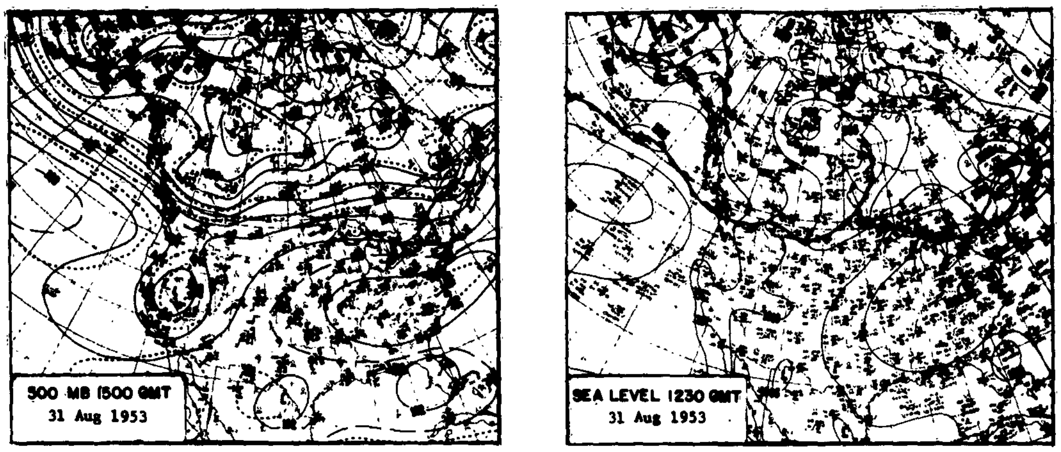


Figure 16. --Continued.

Southeast Region

The Southeast region includes Alabama, Georgia, Florida, South Carolina, Virginia, West Virginia, and the Appalachians of eastern Kentucky and eastern Tennessee.

Days with fire load indexes of 17 or higher were selected for investigation of the associated synoptic weather types. For the 6 months of highest fire danger at each of the 10 stations in the region the 99th percentile fire load index ranged from 14 at Richmond, Va., to 23 at Columbia, S.C. The figure 17 was the average for the 10 stations. (More detailed information on the distribution of fire load indexes is found in Appendix A.)

Two hundred cases of fire load index 17 or higher occurred during the 10-year study period. In most cases high fire danger affected only a small portion of the area, often showing up at only one or two stations. Since the region is large and the stations are widely separated, it is possible that the danger existed over wider areas than the station data indicated. There were a few cases where as many as 5 of the 10 stations had high fire danger on the same day. Six stations were affected during the same case but not all on the same day.

In most of the cases the high fire danger lasted only one day, but a few continued for as long as four days. The strong gradient around the periphery of the high pressure areas where the fire danger occurs is a very transitory condition in the Southeast. Occasionally, different weather types with high fire danger occurred consecutively, prolonging the danger period.

For the Southeast region the cases of high fire danger were divided into five synoptic types:

1. Pacific High
2. Northwest Canadian High
3. Hudson Bay High
4. Bermuda High
5. Tropical Storm

In all but a few cases of the first three types, the high fire danger occurred in either the post-frontal or the pre-frontal area of the High. The high fire danger usually occurs in the post-frontal area when the High passes to the north of the region, and in the pre-frontal area when the High passes to the south.

The Bermuda type includes those cases in which a High of Pacific or Canadian origin became part of the semi-permanent Bermuda High.

Of the 200 Southeast region cases of high fire danger, 103 occurred in spring, 41 in summer, 47 in fall, and 9 in winter (table 3). The Pacific and Bermuda High types were associated with the highest fire load indexes; the Hudson Bay and Bermuda Highs with the greatest number of days per case (table 4).

The Pacific High Type

The Pacific High type was the most numerous, accounting for 32 percent of the 200 cases. In this type, a portion of the Pacific High enters the Pacific Northwest or British Columbia and is steered to the southeast by the flow aloft. The track taken by the High varies with the amplitude of the flow pattern aloft and with the changes that take place in the flow aloft during the life history of the type.

When the upper flow pattern has little amplitude, the path of the High is from the Pacific Northwest directly to the northern portion of the Southeast region. If the air ahead of the preceding front has ample moisture, there are showers along and ahead of the front and high fire danger does not occur. Dry air ahead of the front results when moisture from the Gulf is cut off by a ridge extending eastward from Texas or when a previous frontal passage has precipitated much of the available moisture. In such cases, the low-level flow ahead of the front is generally westerly and the front passes without showers.

Table 3.--Number of cases with fire load index 17 and above by synoptic types and months, Southeast region, 1951-60

Type	Winter			Spring			Summer			Fall			Total	Percent
	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.		
Pacific High														
Post-frontal	0	0	1	1	6	11	4	0	2	3	1	1	--	--
Pre-frontal	2	0	3	4	7	7	1	0	0	2	3	4	--	--
Other	0	0	0	0	0	1	0	0	0	0	0	0	-- 64	-- 32
NW Canadian High														
Post-frontal	0	0	1	7	4	4	1	0	0	1	6	3	--	--
Pre-frontal	0	0	0	2	1	4	0	0	0	1	1	1	--	--
Other	0	0	0	0	2	0	0	0	0	0	0	0	-- 39	-- 20
Hudson Bey High														
Post-frontal	0	0	0	0	4	5	2	0	1	2	1	0	--	--
Pre-frontal	0	0	0	1	2	2	1	0	0	3	0	0	--	--
Other	1	1	0	1	1	0	0	0	0	1	0	0	-- 29	-- 14
Bermuda High	0	0	0	4	12	7	12	8	6	7	0	0	56	28
Tropical Storm	0	0	0	0	1	2	2	1	0	4	0	2	12	6
Total	3	1	5	20	40	43	23	9	9	24	12	11	200	100

Table 4.--Number of cases with highest fire load index and average and greatest number of days per case by synoptic types, Southeast region, 1951-60

Type	Highest fire load index equal or greater than--										Avg.no.of days/case	Greatest no. days/case
	17	20	25	30	35	40	45	50	55	60		
Pacific High												
Post-frontal	30	24	8	5	2	1	0	0	0	0	1.2	2
Pre-frontal	33	22	7	2	1	1	1	1	1	0	1.3	3
Other	1	1	0	0	0	0	0	0	0	0	1.0	1
Northwest Canadian High												
Post-frontal	27	20	10	6	3	1	0	0	0	0	1.1	2
Pre-frontal	10	8	1	0	0	0	0	0	0	0	1.2	2
Other	2	1	0	0	0	0	0	0	0	0	1.0	1
Hudson Bay High												
Post-frontal	15	10	1	1	1	1	1	0	0	0	1.1	2
Pre-frontal	9	8	3	1	1	0	0	0	0	0	1.8	4
Other	5	3	0	0	0	0	0	0	0	0	1.4	3
Bermuda High	56	37	13	8	3	2	1	1	1	1	1.4	4
Tropical Storm	12	8	4	0	0	0	0	0	0	0	1.2	2
Total or average	200	142	47	23	11	6	3	2	2	1	1.2	--

After the frontal passage the dew point falls, and since the leading edge of the Pacific air mass is not very cool, the relative humidity drops rapidly. Increasing winds result in high fire danger. By the following day the gradient decreases, temperatures may be a little lower, and relative humidities a little higher, and, at any rate, the fire danger decreases.

The period April 5-8, 1956, illustrates this type (fig. 17). A portion of the Pacific High entered the northwestern states on April 5 and 6 and moved rapidly southeastward. A cold front passed through the Southeast region on April 6 and was accompanied by scattered showers. The weak High to the rear of this front was dry enough so that a second front could pass without rain and with much lower humidities and strong winds on April 7. In the post-frontal area Macon, Ga., had a fire load index of 40 on April 7; Tallahassee, Fla., had 29; Orlando, Fla., 18; and Columbia, S.C., 20. Fire danger continued high on April 8 with Orlando having 17, Macon 34, Tallahassee 18, Montgomery, Ala., 18, and Columbia 24.

Occasionally the Pacific High moves more eastward through the northern United States or southern Canada under a generally zonal flow pattern aloft which is changing to a meridional or a blocking pattern. As the upper flow becomes more northerly over the High, the High turns southward and moves rapidly into the Southeast region. This is usually a case where the Gulf moisture is cut off, and high fire danger occurs in the post-frontal area as in the previous situation.

The period June 25-29, 1954 (fig. 18) illustrates this type. The Pacific High moved eastward along the Canadian border to the Great Lakes. There, it began moving southward influenced by the northerly upper flow on June 27. Meanwhile, a large east-west ridge from Texas eastward kept the Gulf moisture cut off from the northern part of the region. The low-level flow ahead of the front was mostly north to northwest. A double frontal structure was present in this case also, but since the moisture supply over the northern portion of the region was already low it contributed little if any toward achieving a dry frontal passage on June 28. On this day Montgomery, Ala., had a fire load index of 17, Columbia, S.C., 31, and Knoxville, Tenn., 20. On June 29, decreasing gradient, lower temperatures, and higher humidities lowered the fire danger.

Still another track is taken by the Pacific High when a strong upper trough is located in the Great Plains. Under these conditions the High moves rapidly to Texas and spreads eastward over the southern portion of the region. At the same time the upper ridge weakens and moves eastward also.

When the Pacific High is over the region the upper flow becomes anti-cyclonic--a condition Krueger and Pachence[4] found conducive to subsidence. The increasing gradient in the northwest portion of the High with the approach of the next front produces high fire danger. As the front approaches, moisture increases and the fire danger diminishes.

The period from October 23 to 29, 1955 is a typical case (fig. 19). The Pacific High, which was in northwestern United States on October 23, moved southeastward in the northerly flow on the east side of the meridional ridge aloft. The High reached Texas October 24, then spread eastward over the southern portion of the region on October 25. By then, the upper ridge was weakening and the upper flow over the region was becoming anti-cyclonic. High fire danger occurred in the north and northwest portions of the High as the gradient increased with the approach of the next front on October 26 and 27. Showers accompanied the front on October 28 and 29, and the fire danger decreased.

The Northwest Canadian High Type

The Northwest Canadian High type accounted for 19 percent of the 200 cases of high fire danger in the Southeast region. This type is similar to the Pacific High type, but the Canadian air mass is somewhat drier and cooler.

Under a favorable steering pattern aloft, the High leaves its source region and a continental polar (cP) air mass moves southeastward. Although the air mass is originally quite cool, it becomes warmed by moving to lower latitudes, by passing over a warmer surface, and by receiving more effective solar radiation. In addition, the air is warmed adiabatically by subsidence in the High. When the air mass reaches the Southeast its relative humidity is quite low. This dryness, combined with moderate or strong winds in the areas of strong pressure gradient around the periphery of the High, produces high fire danger. Since this is a moving system, the period of high fire danger in any one area is usually only one day in length.

The flow pattern aloft must be meridional with the ridge in the extreme western part of the continent in order for the Northwest Canadian High to be steered to the Southeast region. The surface High plunges southeastward following the passage of a short-wave trough aloft and a Canadian cold front at the surface.

4/ Krueger, D.W. and A. Pachence. Subsidence as a cause of dry surface air in southeastern United States. Paper presented at Fifth National Conference on Agricultural Meteorology, Lakeland, Florida, April, 1963.

The area of high fire danger can be either on the forward side of the High in the post-frontal area, or on the rearward side of the High in the pre-frontal area. In about three-quarters of the Northwest Canadian High cases, the high fire danger occurred in the post-frontal area after the passage of a dry cold front. This was true in only about half of the Pacific High cases. The rather dry air ahead of the Canadian front is frequently Pacific air which moves over the region just prior to the invasion of Canadian air.

The period May 14-17, 1956 (fig. 20) illustrates this type. May 14 a Bermuda High with warm moist air was located over the region. A weak Pacific front extending from the Great Lakes to Texas was moving eastward and was followed by somewhat drier air. The Canadian High was located northwest of Hudson Bay. May 15 moist Bermuda air continued over most of the region, but Pacific air moved over the northern portion. The Canadian High began to move southeastward under strong northwesterly flow aloft following a short-wave trough. By May 16 the Pacific front had moved through the region, produced scattered showers, and was followed by somewhat drier air. This drier air over the region permitted the Canadian front to pass without showers. The resultant dry air and strong winds produced high fire danger. The Canadian High moved rapidly through the region, and by May 17 the gradient was weak, moisture was beginning to increase, and the fire danger lowered.

In situations where the flow aloft has much larger amplitude and the ridge is farther west, the Canadian High pushes southward into Texas before spreading eastward over the region and causing high fire danger in its northern and pre-frontal quadrants. These cases are much less frequent than the one just described but when they do occur the conditions are very similar to the corresponding Pacific High cases.

The surface and 500 mb charts for March 18-25, 1951 (fig. 21) provide an example of this type. March 18 a portion of the Northwest Canadian High had already reached the southern Plains; and it spread farther southward through Texas March 19. The ridge aloft was located at about 130°W, had large amplitude, and strong northerly winds on the east side. During the next several days the surface High spread slowly eastward while the flow aloft changed from a large amplitude meridional pattern to a zonal pattern. Slight anti-cyclonic curvature, which favors subsidence, developed over the region by March 22. High fire danger occurred in parts of the region March 23 as the gradient and the winds increased in advance of the approaching cold front. Only scattered showers accompanied the front as it moved through the region March 24. High fire danger continued in the post-frontal area of the next High which was of Pacific origin. Fire danger decreased when the gradient relaxed on March 25.

The Hudson Bay High Type

For a High from the Hudson Bay area to reach the Southeast region the flow aloft must be strongly meridional and the ridge must be well inland from the West Coast. Since such extreme amplitude is infrequent, fewer cases of the Hudson Bay type are found. Only 14 percent of the total of 200 cases were of this type. The months with the most cases were April and May. Only two cases were found in March whereas the Northwest Canadian type was more frequent in March than in any other month. The seasonal shift to this type is probably due to Hudson Bay remaining ice-covered long after northwest Canada begins to warm up. This can also account for slight differences in air mass properties between the two areas: the Hudson Bay air mass tends to be cooler and drier than the Northwest Canadian air mass in late April and May. When the Hudson Bay High reaches the Southeast region, the fire weather is similar to that produced by the Northwest Canadian High. The post-frontal area is usually where high fire danger occurs. When the High moves far enough south to have high fire danger on the north or northwest side it usually merges with the Bermuda High.

The map series May 5-11, 1951 (fig. 22) illustrates a case where high fire danger occurred after the frontal passage and again after the Hudson Bay High joined the Bermuda High. May 5 the Hudson Bay High began moving slightly west of south under the northeasterly flow aloft and behind a short-wave trough moving through the meridional long-wave pattern. May 6 it was moving through the Plains, and the leading edge penetrated the Southeast, bringing high fire danger in the strong gradient area on this and the following day. By May 8 the gradient had relaxed and the fire danger decreased. On May 9 this High had joined the Bermuda High and fire danger again increased, this time on the northwest side. High fire danger continued on May 10 in the pre-frontal area and lowered on May 11 with frontal showers.

The Bermuda High Type

The Bermuda High type is usually rather stagnant, persisting over the region for long periods of time, mostly in late spring, summer, and early fall. The surface pressure pattern is characterized by a westward extension of the Bermuda High, often well into Texas. Gulf moisture is cut off. The southeastern portion of the country is usually dry, except for occasional widely-scattered showers. This is the typical drought type for this portion of the country and, sometimes, adjacent portions as well.

Aloft the flow pattern may be either meridional or zonal, but in any case the long-wave ridge is located over the central part of the continent and the belt of westerlies is far to the north near the Canadian border.

Under such conditions the type of High over the region is probably not related to the high fire danger. The fire danger decreases as the gradient weakens when the storm moves away or when precipitation begins as the storm approaches. Six percent of the 200 high fire danger cases were of this type.

The situation on September 6-11, 1954 (fig. 24) illustrates the tropical storm type. September 6 a Bermuda High was over the region, and a hurricane (Edna) was located near Turks Island. During the next 4 days the hurricane intensified as it moved steadily northwestward toward the Georgia coast. September 10 the storm was off the Georgia-South Carolina coast and moving northward. Strong winds produced high fire danger in eastern Georgia and South Carolina. On September 11 the storm moved northeastward off shore. Fire danger in the South Atlantic states lowered as the gradient weakened.

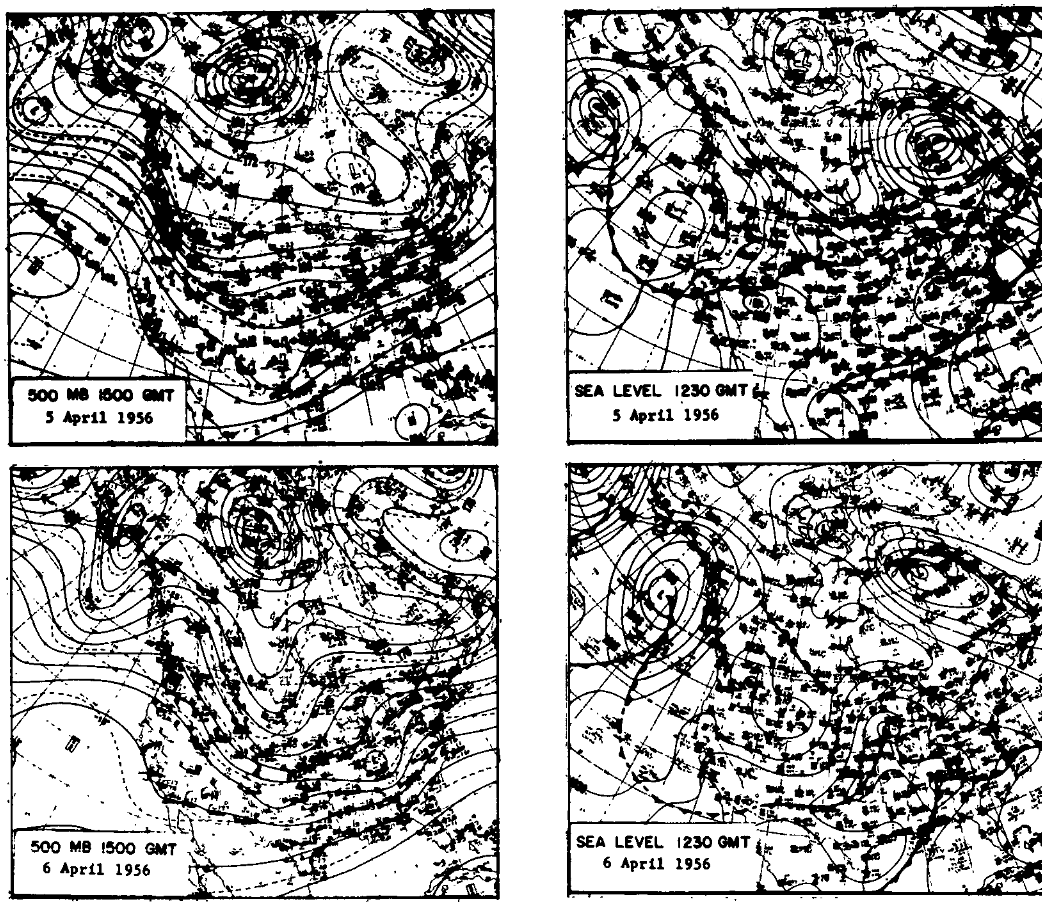


Figure 17.--Surface and 500 mb charts, April 5-8, 1956. High fire danger occurred April 7 and 8.

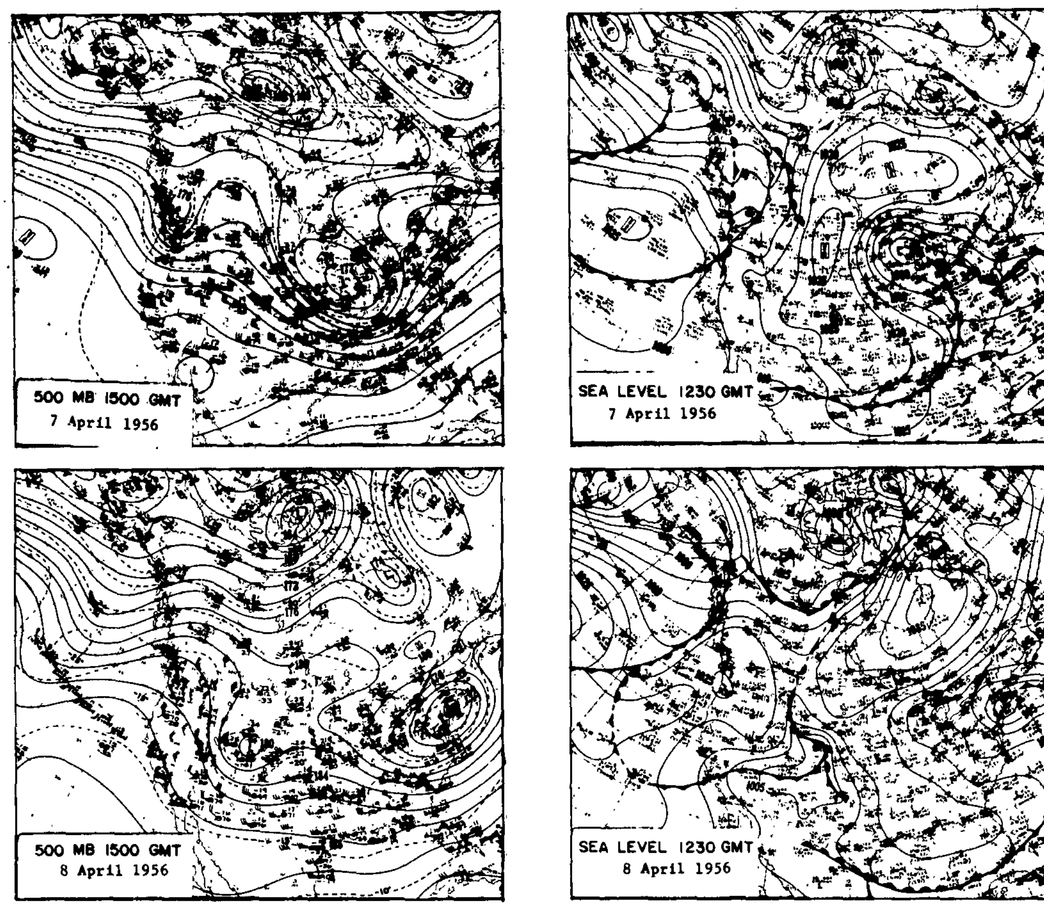


Figure 17. --Continued.

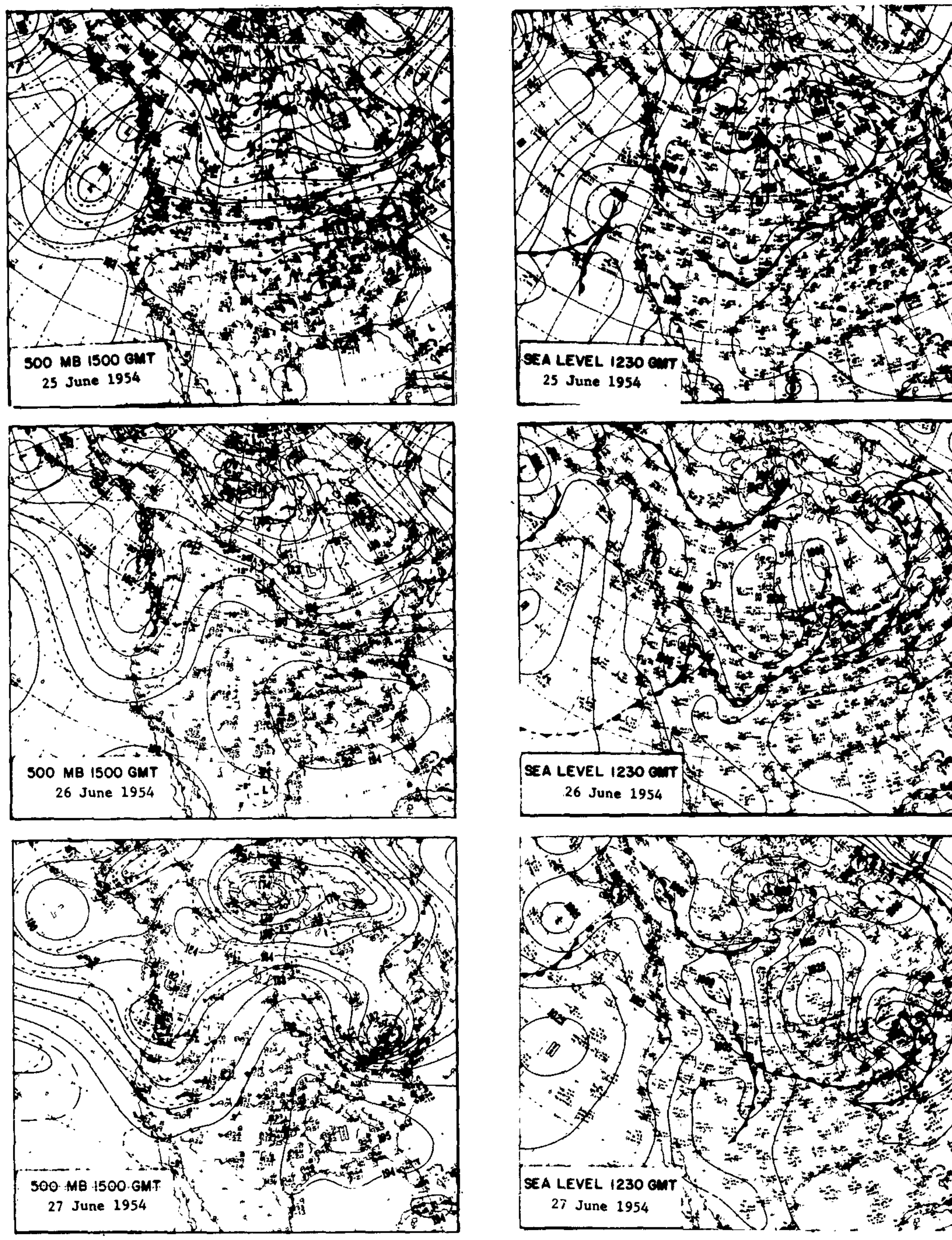


Figure 18.--Surface and 500 mb charts, June 25-29, 1954. High fire danger associated with the Pacific High occurred in the post-frontal area on June 28.

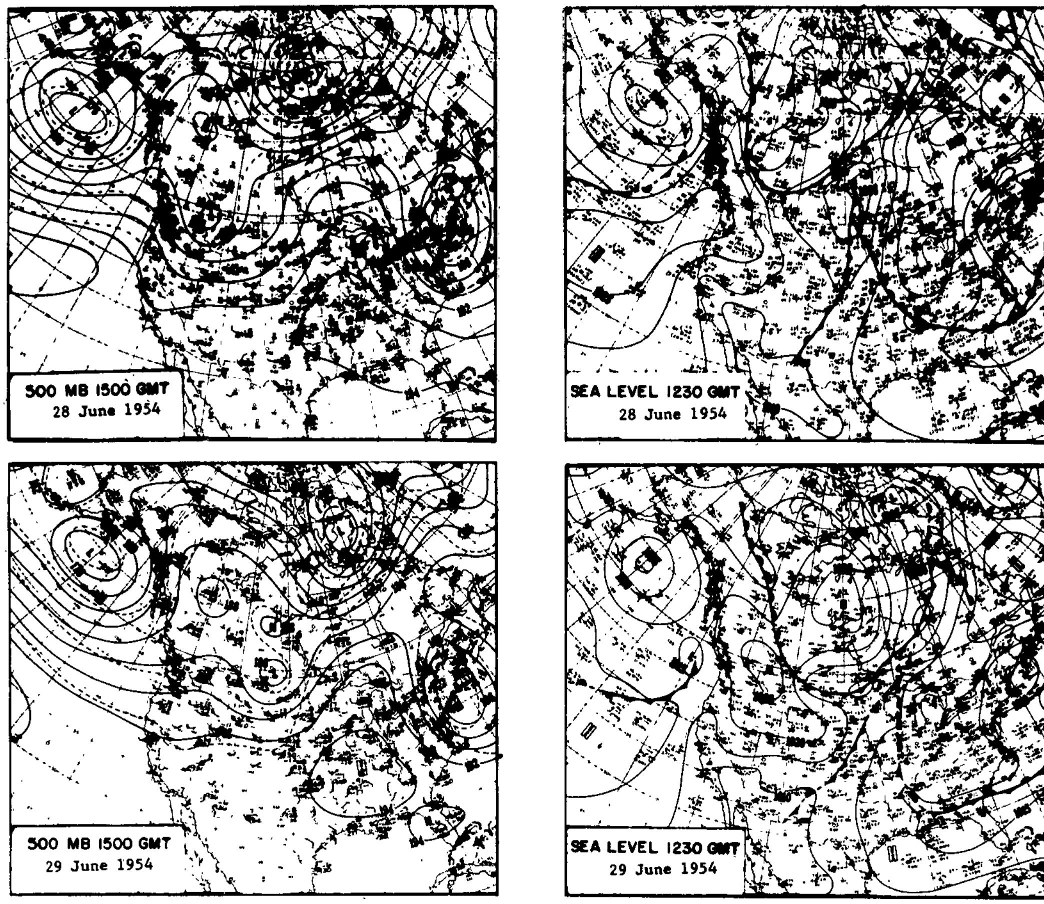


Figure 18. --Continued.

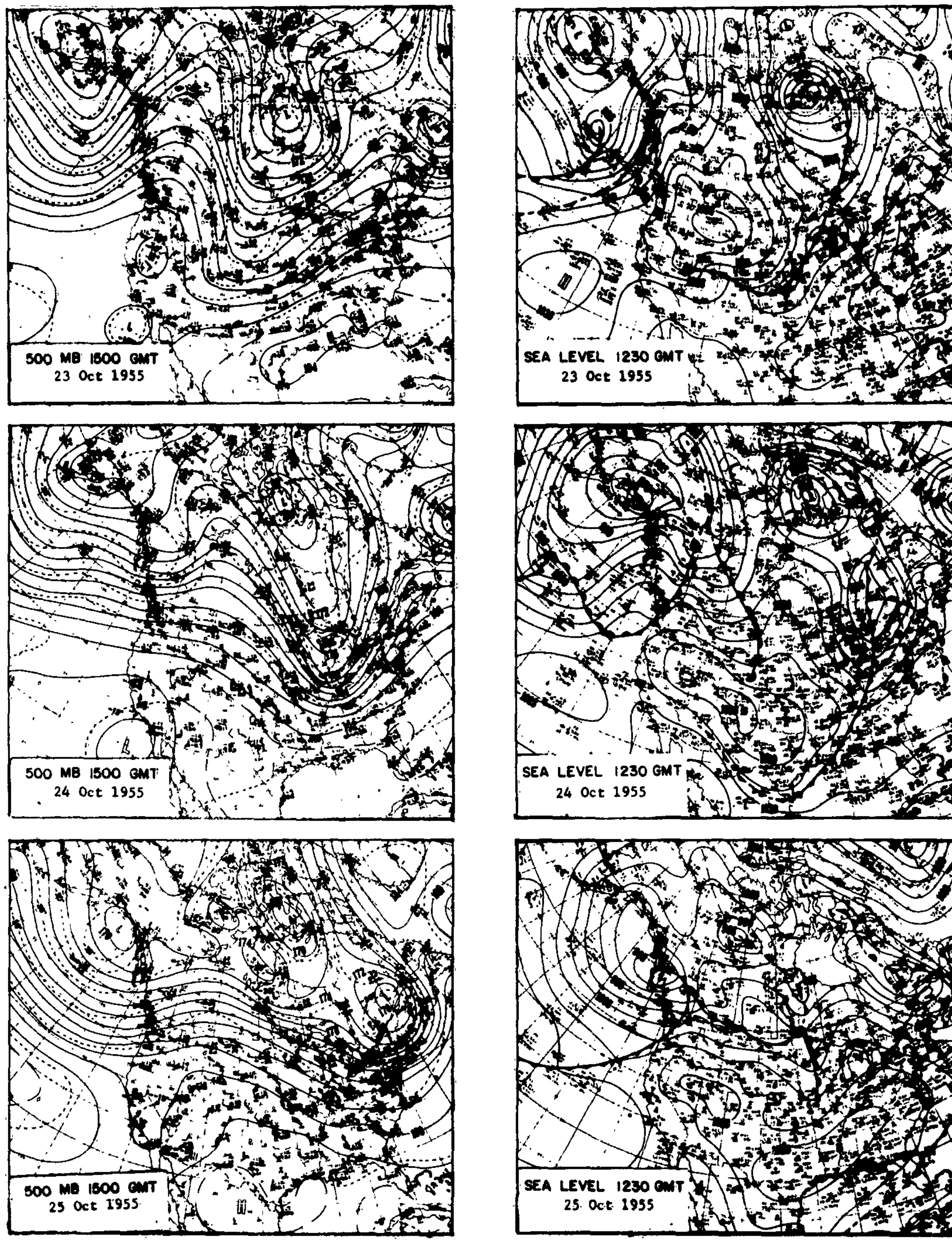


Figure 19. --Surface and 500 mb charts, October 23-29, 1955.

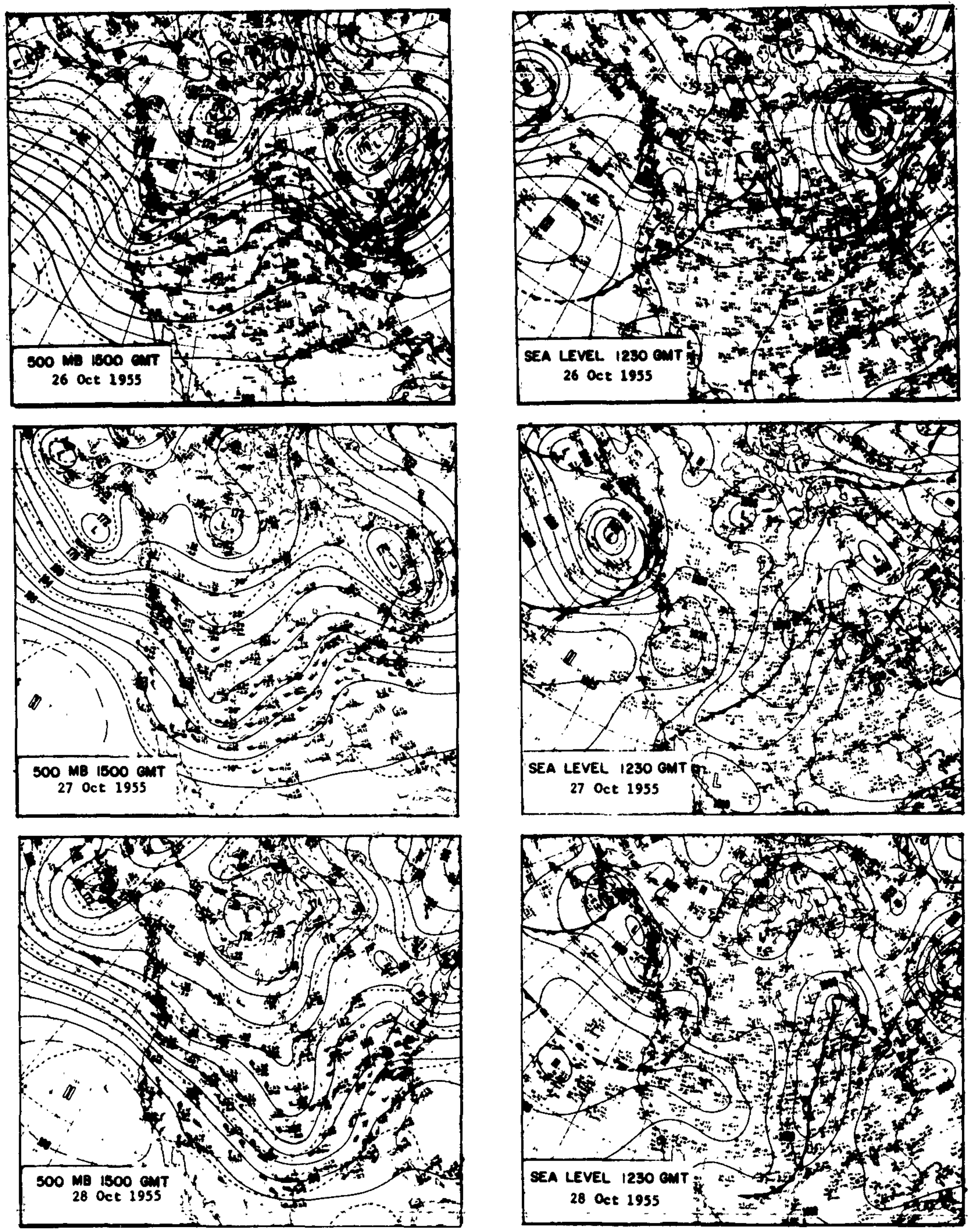


Figure 19.--Continued.

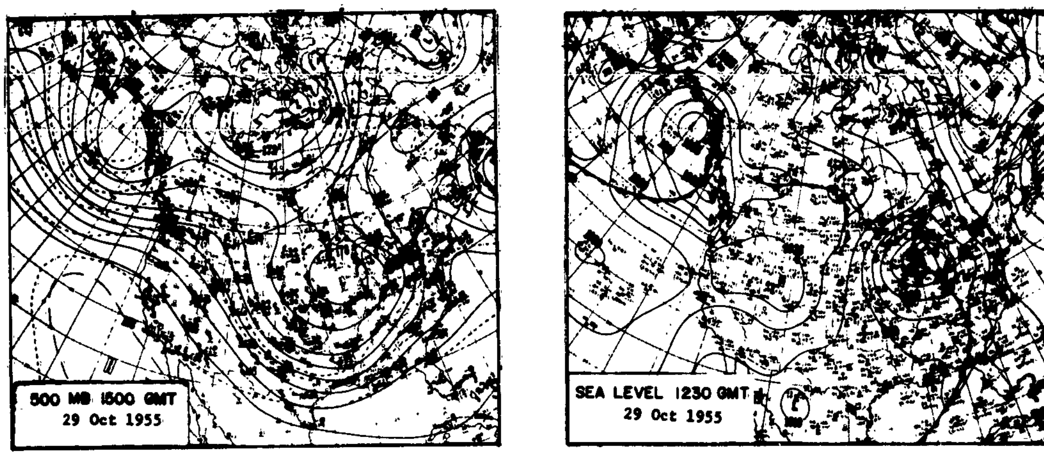


Figure 19. --Continued.

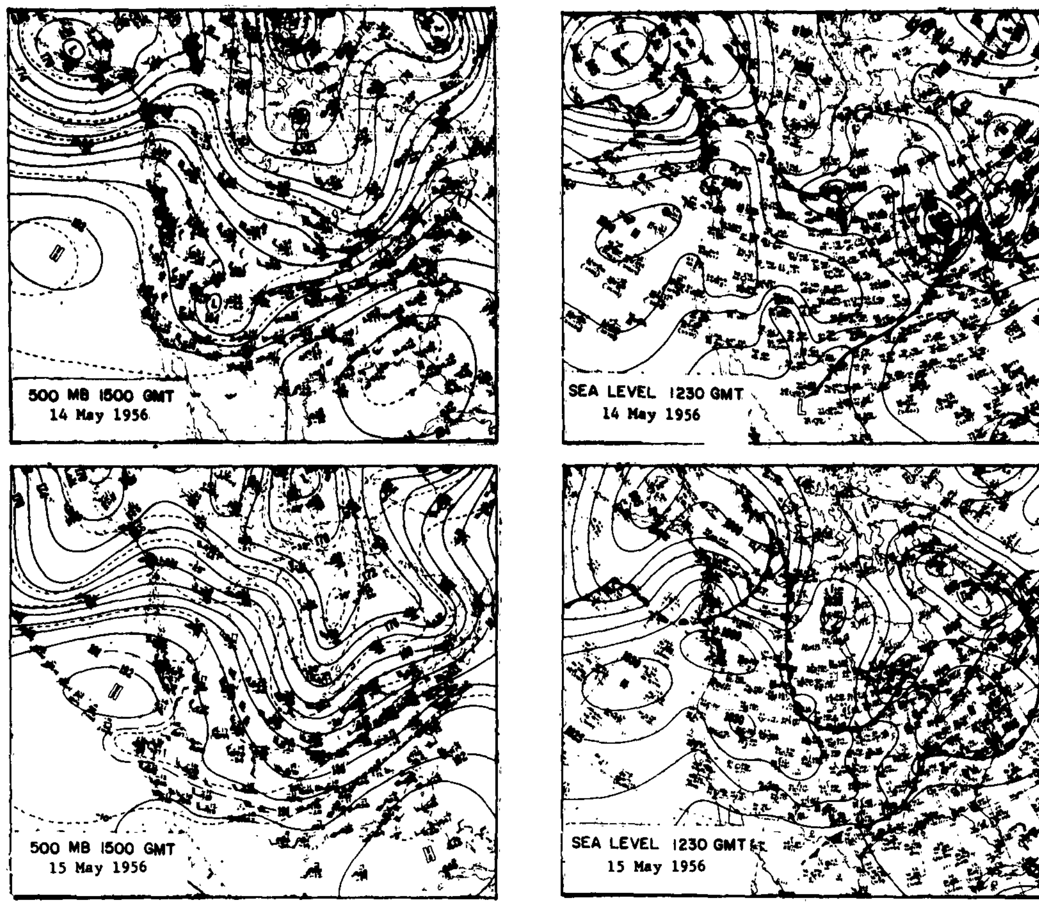
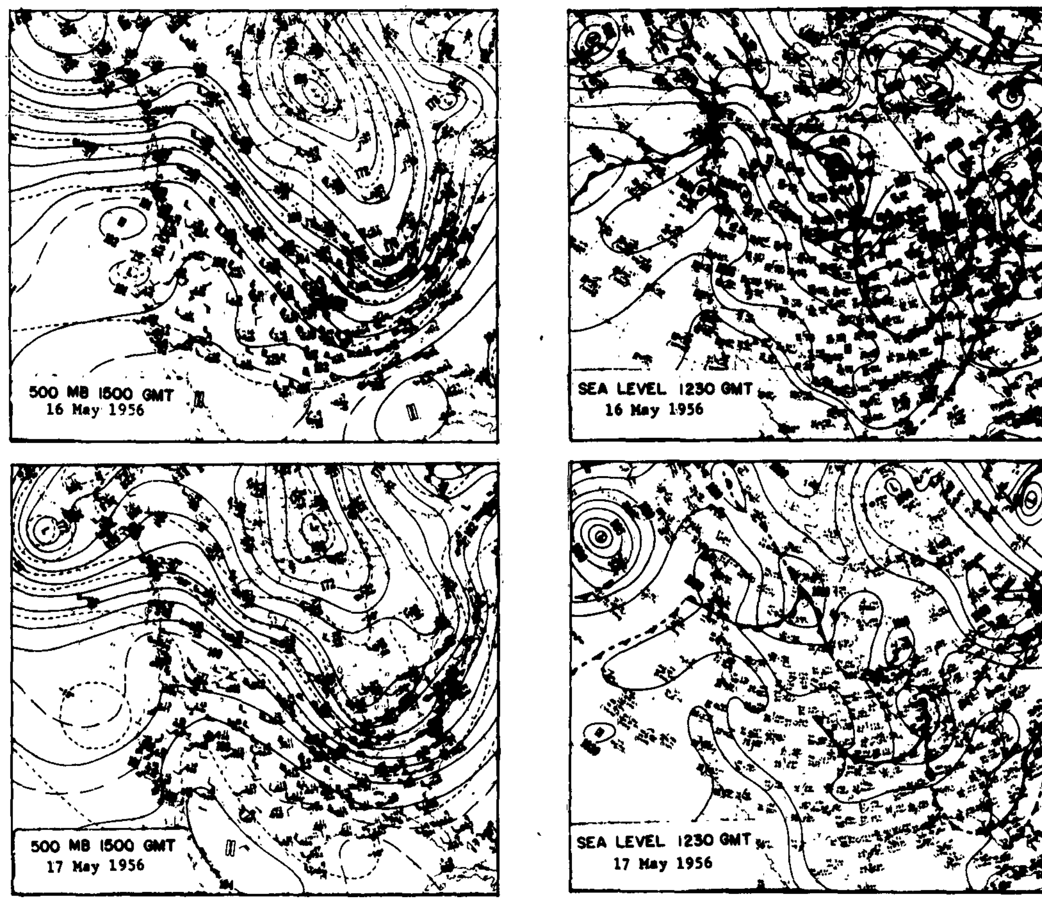


Figure 20.--Surface and 500 mb charts, May 14-17, 1956. High fire danger associated with the Canadian High occurred May 16.



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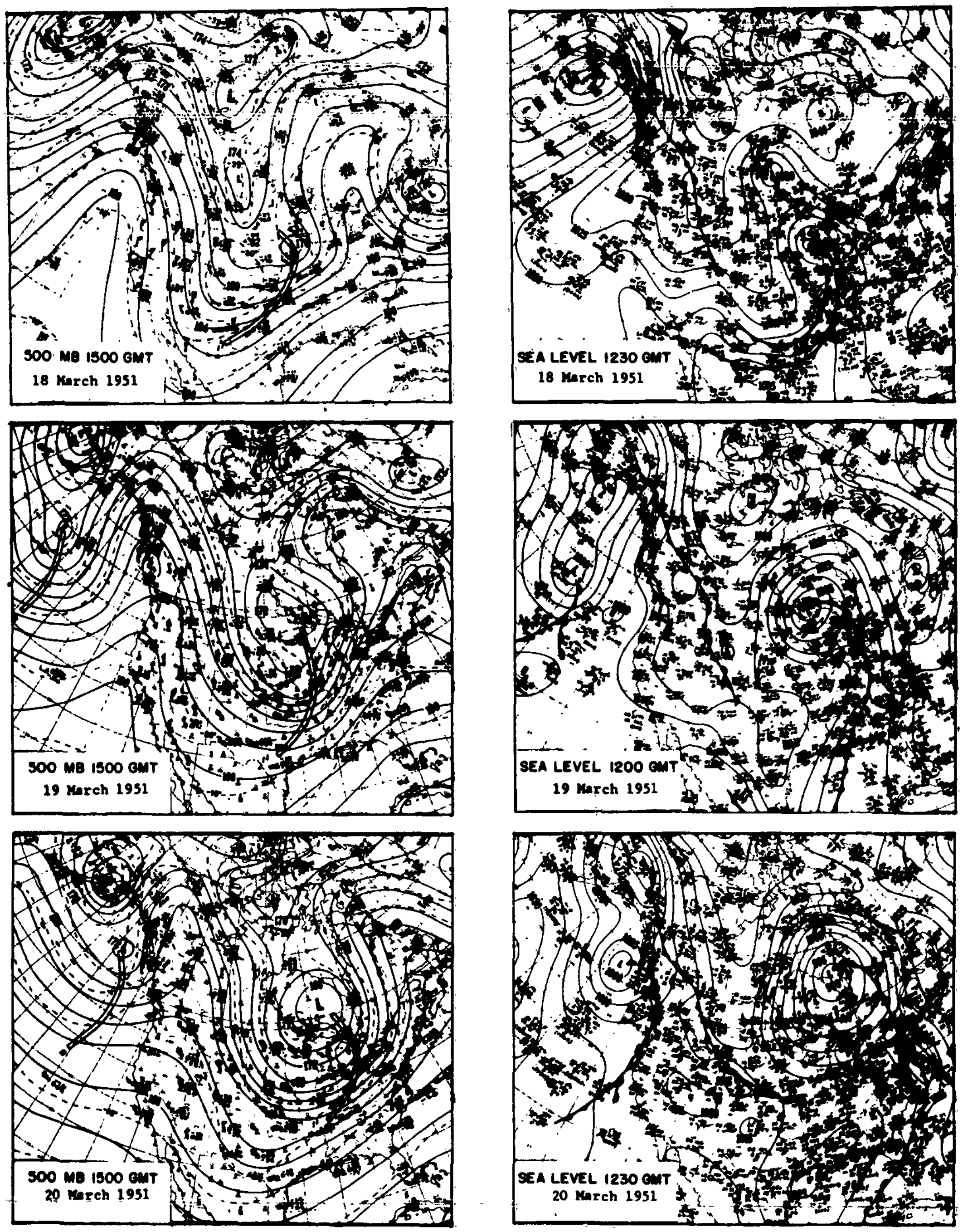
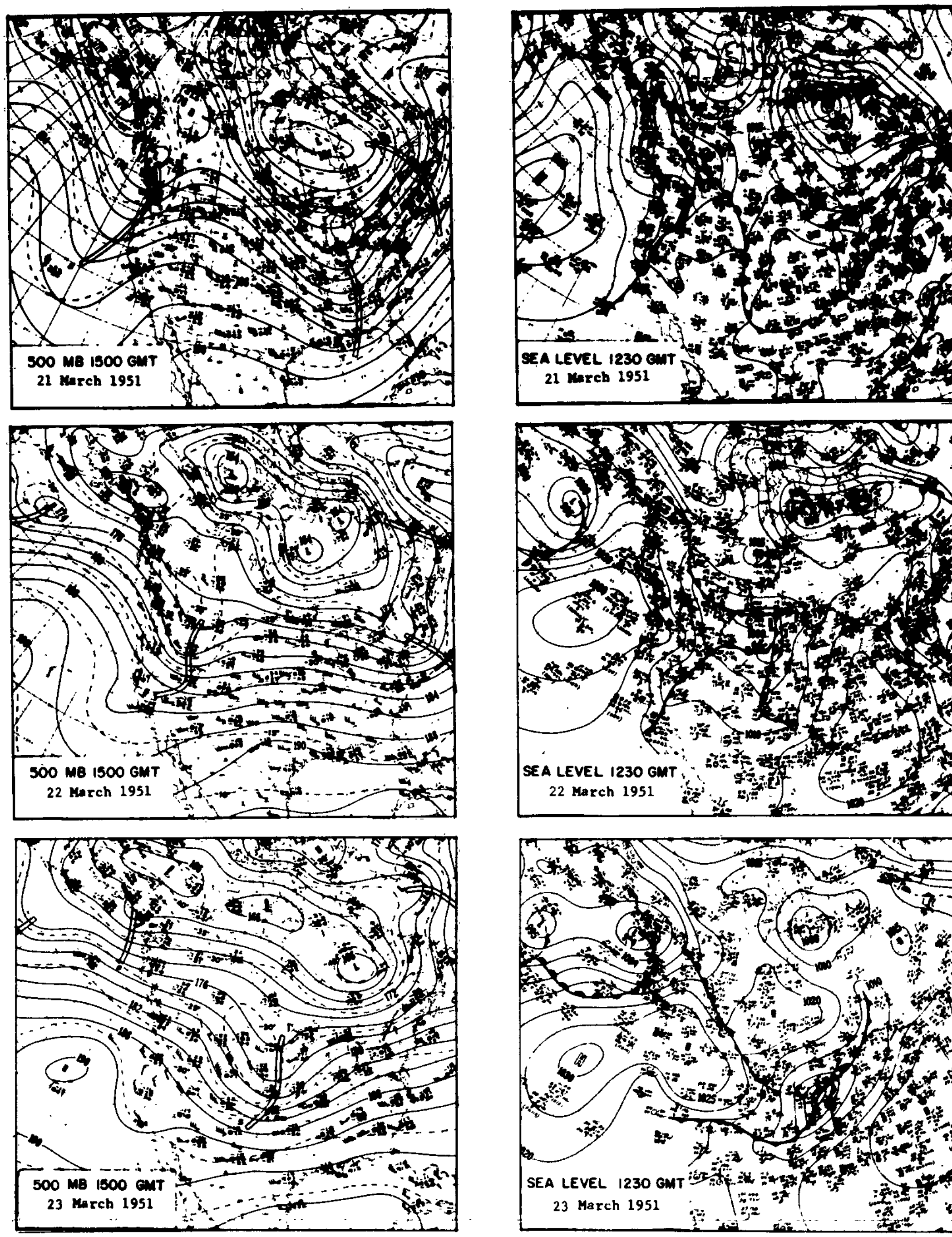


Figure 21.--Surface and 500 mb charts, March 18-25, 1951. High fire danger associated with the pre-frontal area of the Canadian High occurred March 23.



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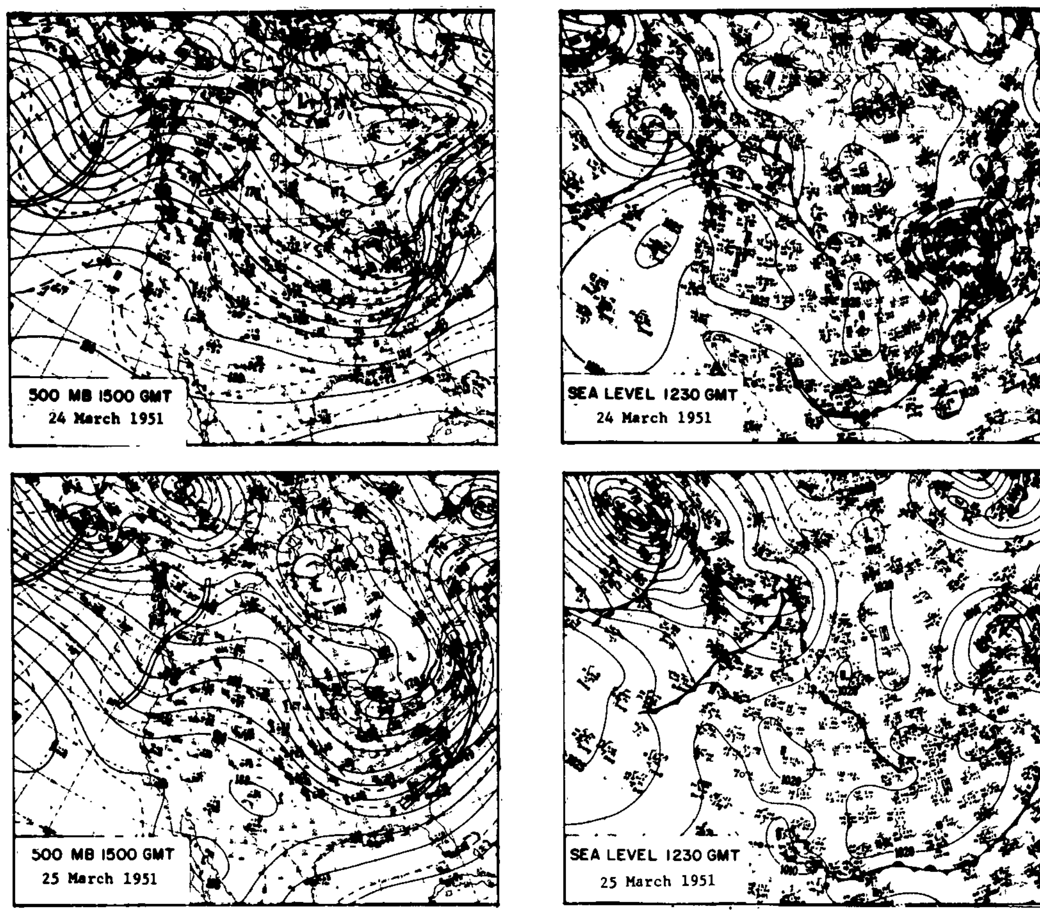

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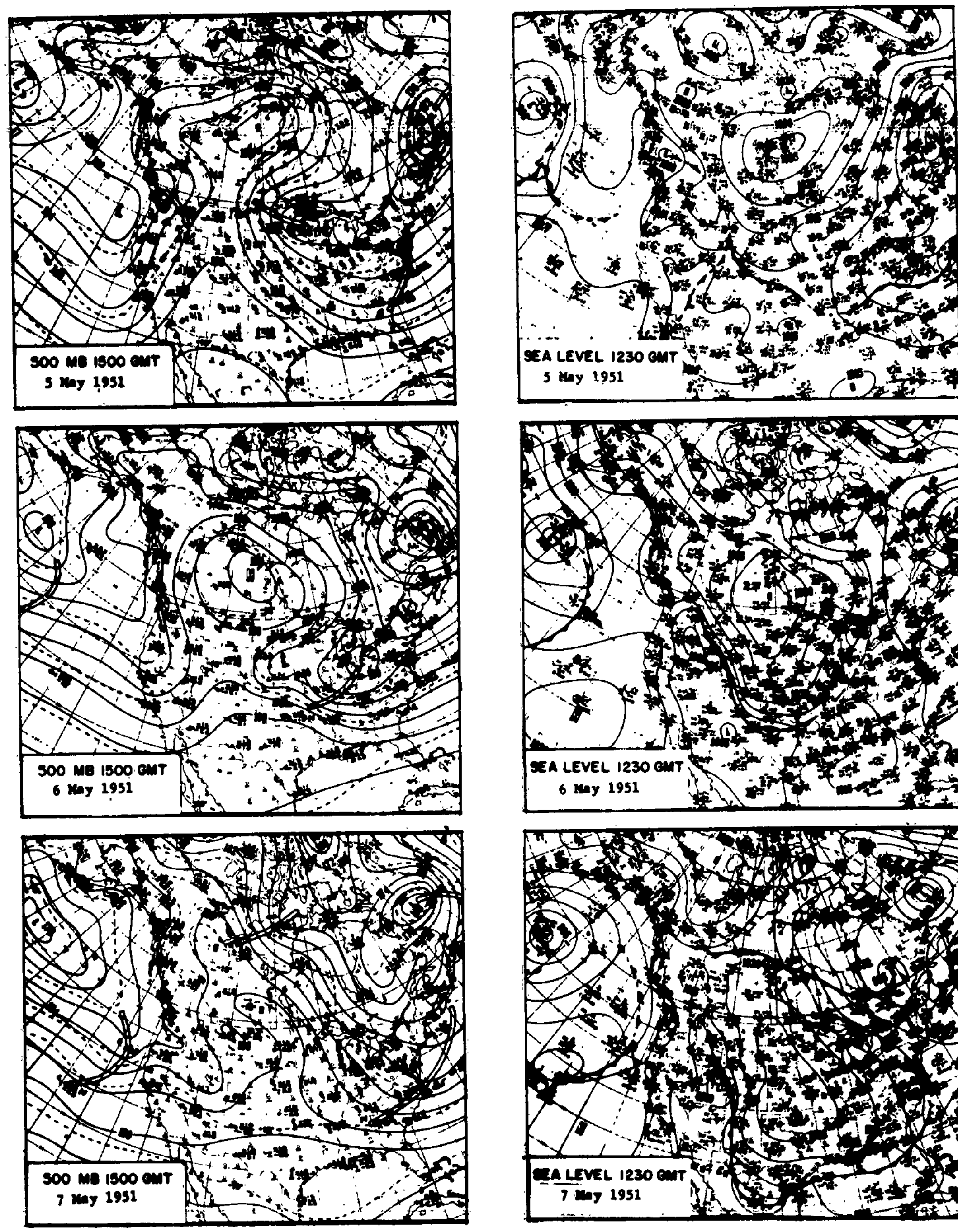
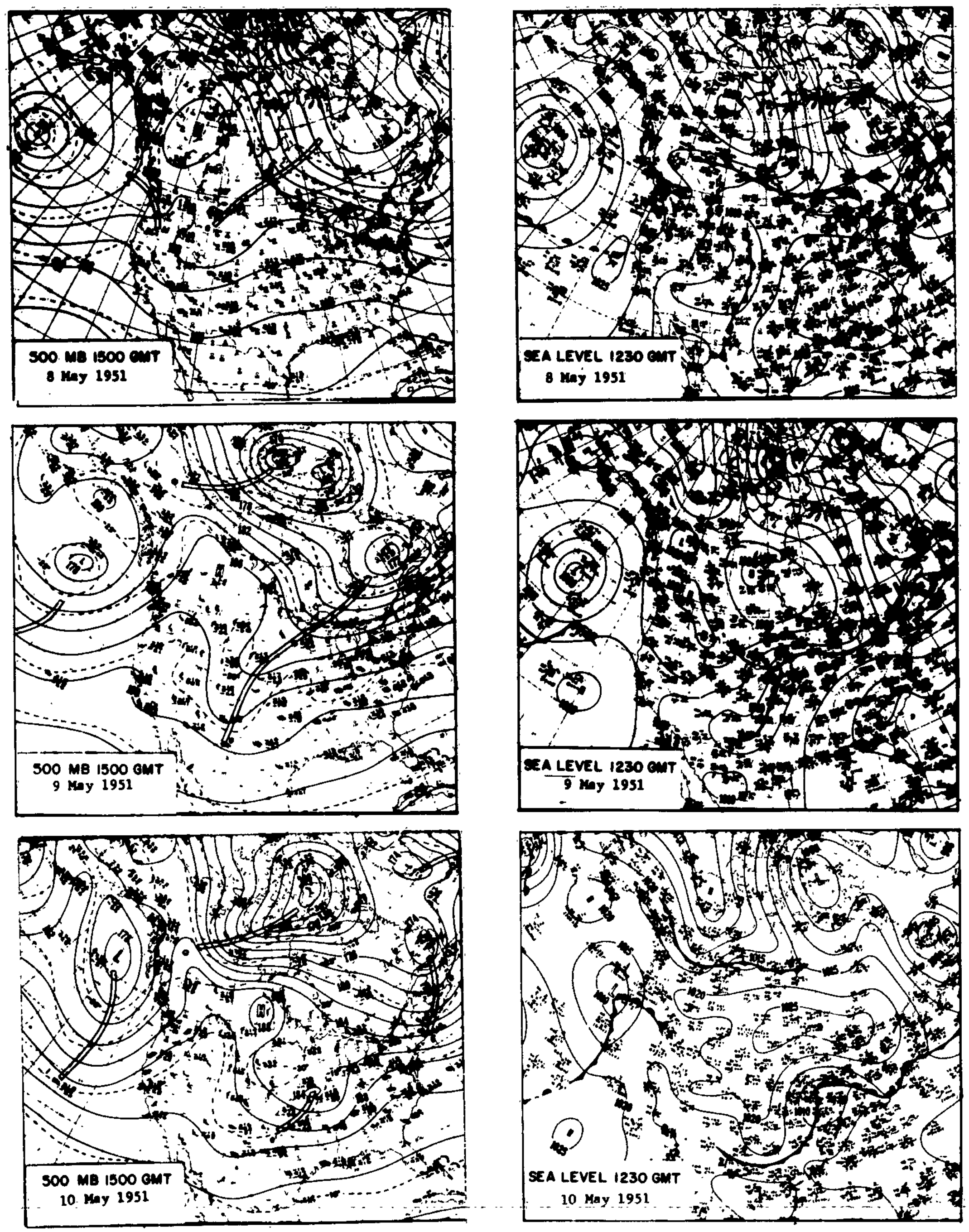


Figure 22.--Surface and 500 mb charts, May 5-11, 1951. High fire danger occurred in the post-frontal area May 6 and 7 and in the pre-frontal area May 9 and 10.



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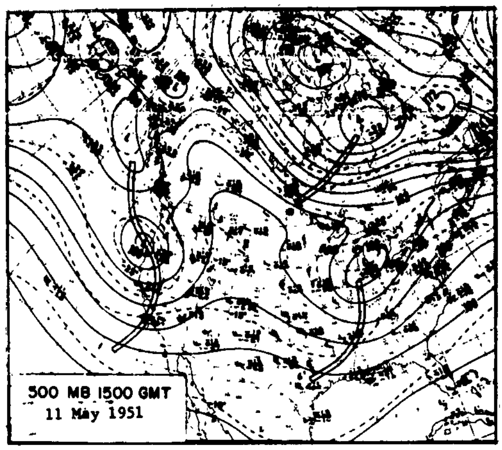


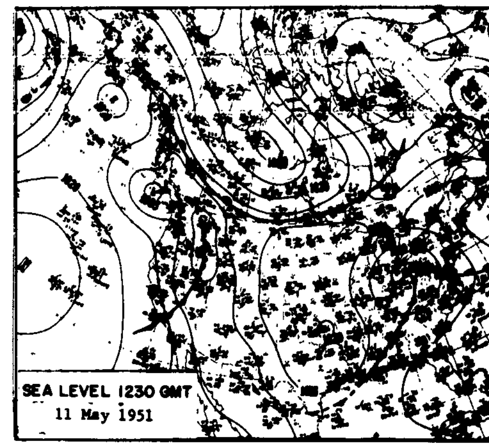


Figure 22. --Continued.

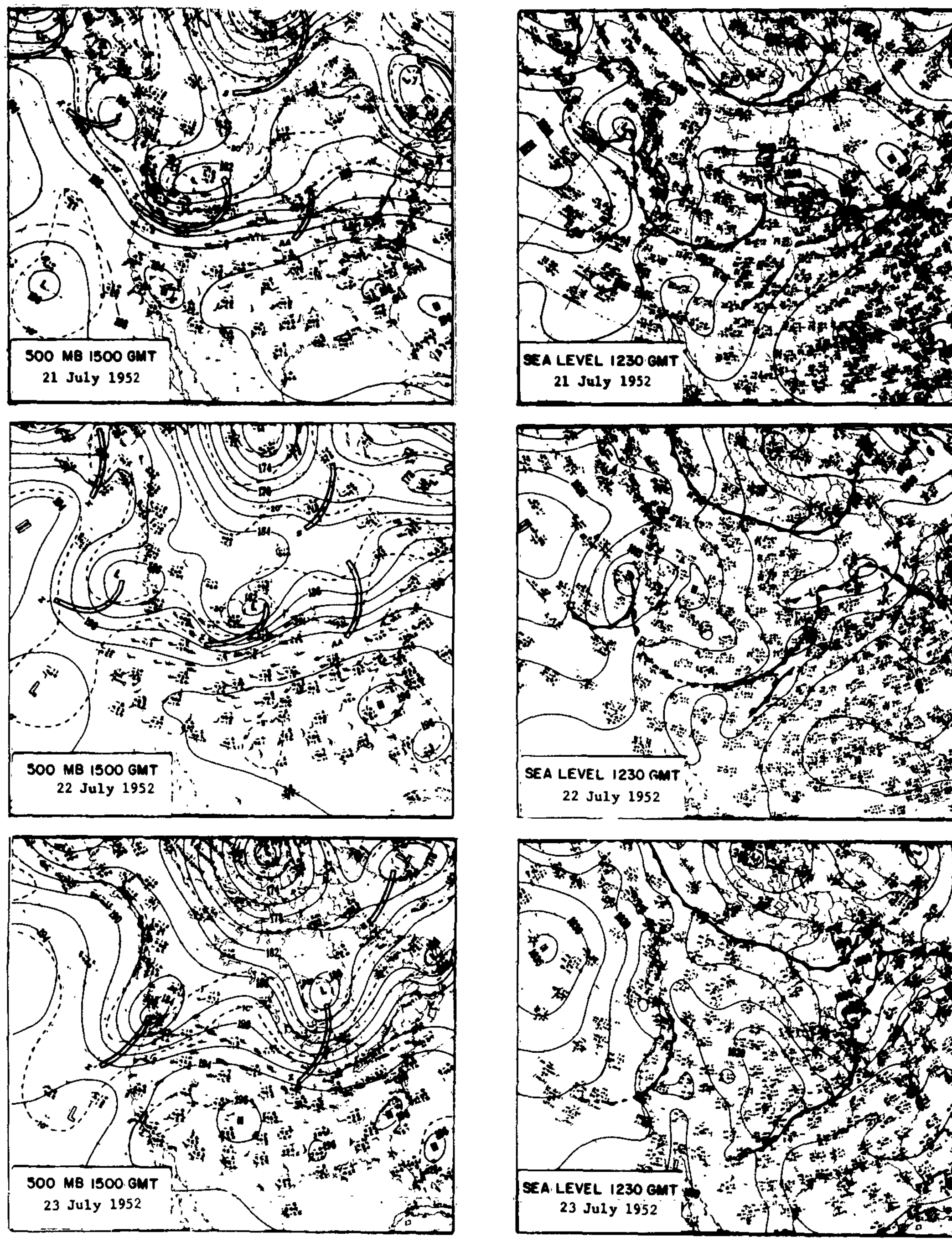


Figure 23. --Surface and 500 mb charts, July 21-25, 1952. High fire danger occurred in the pre-frontal area July 23 and 24.

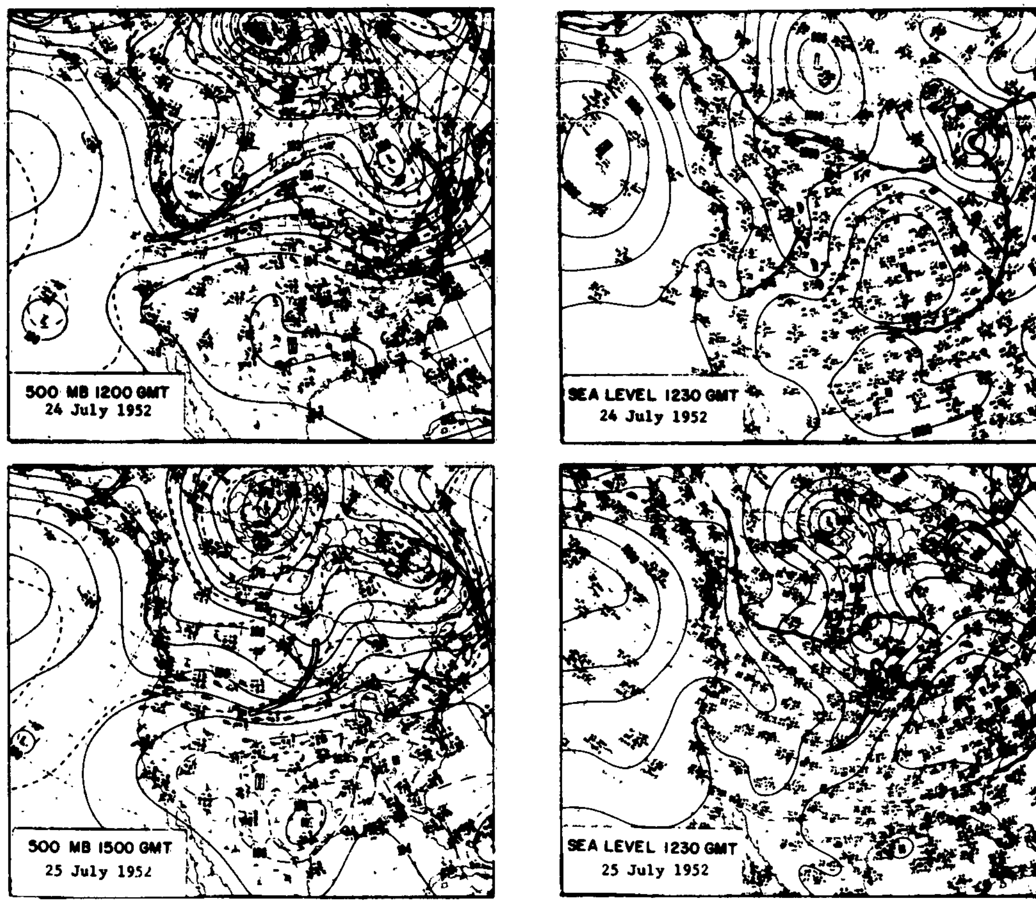


Figure 23. --Continued.

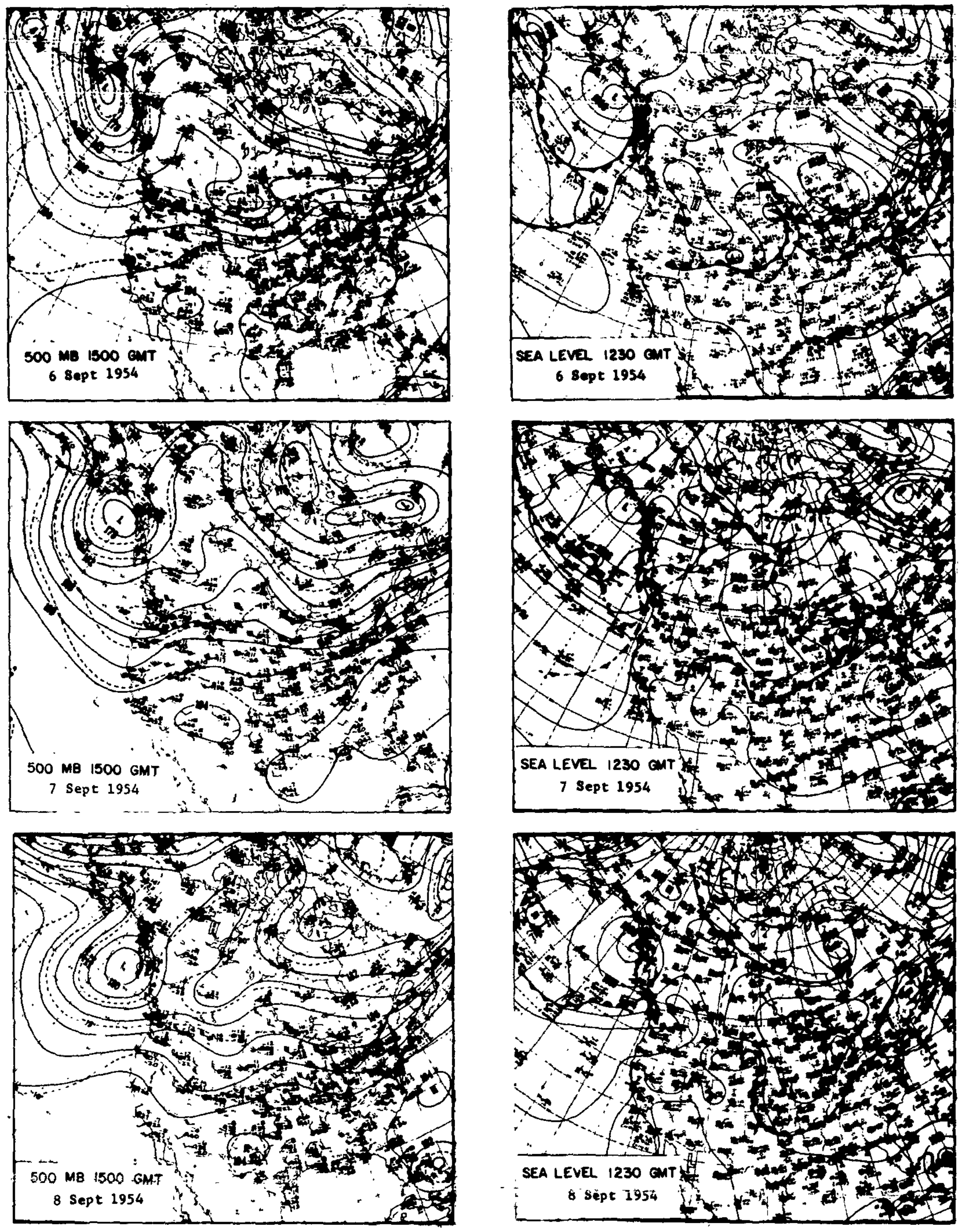


Figure 24. --Surface and 500 mb charts, September 6-11, 1954. High fire danger occurred September 10 in the area of strong winds in Georgia and South Carolina.

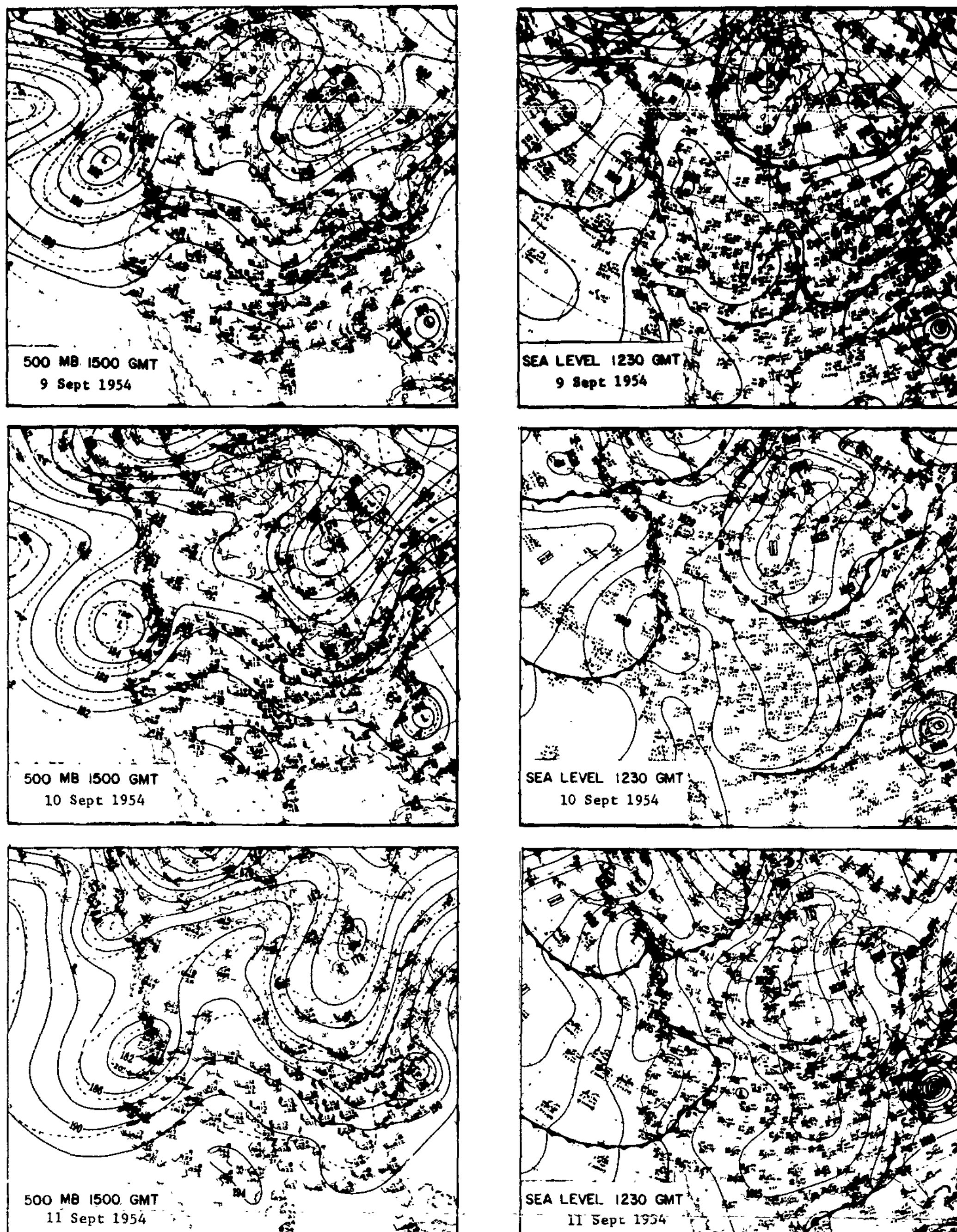


Figure 24. --Continued.

Lake States Region

For purposes of this study the Lake States region includes Michigan, Wisconsin, northeastern Minnesota, northeastern Illinois, and the northern portions of Indiana and Ohio. The stations used to represent this region were International Falls, Minn., Eau Claire, Wis., Madison, Wis., Chicago, Ill., and Sault Ste Marie, Traverse City, Grand Rapids, and Detroit, Mich.

The fire season in the Lake States in terms of wildland fire occurrence and as measured by the fire danger system used for this study, usually extends from April through October. At the stations used in the Lake States, with the exception of Sault Ste Marie, Mich., the value of fire load index which is exceeded about 1 percent of the time during these months runs from 17 to 24. The air passing over Sault Ste Marie has a water rather than a land trajectory so much of the time that the corresponding 1 percent level of fire load index is about 8.

In the Lake States region, cases were selected for investigation which had fire load indexes of 17 or higher at any station. A check of large fires that occurred in the Lake States during the 10 years of study showed that 7 of the 12 fires burned on days when the fire load index was 17 or higher (table 5). Inspection of the weather maps for the days of three of these fires--on the Nicolet National Forest, on the Chippewa National Forest November 15, 1958, and at Cranberry Rock, Wisconsin--indicates that the fire danger in the fire areas may have been higher than at the observation stations.

Table 5.--Large fires in the Lake States for the period and the associated fire load index at the nearest station, 1951-60

Date	Location	Acreage burned	Fire load index
April 28, 1952	Superior National Forest	803	47
April 21, 1953	Nicolet National Forest	921	11
May 8, 1953	Chippewa National Forest	335	56
October 21, 1956	Chippewa National Forest	450	5
May 7, 1957	Monroe Center, Wis.	1/1,000	22
May 8, 1957	Lower Mich. National Forest	956	18
April 17, 1958	Standish, Mich.	1/1,000	43
May 13, 1958	Ottawa National Forest	333	12
November 15, 1958	Chippewa National Forest	575	2/5
May 1, 1959	Badoura, Minn.	1/12,000	2/56
May 1, 1959	Grantsburg, Wis.	1/15,000	27
May 1, 1959	Cranberry Rock, Wis.	1/1,000	10

1/ Approximate
2/ Computed for Minneapolis data

During the period 1951-1960 a total of 211 days occurred with a fire load index of 17 or higher. Because of duplication at one or more stations, the total represented 320 station days (table 6). Of the four important synoptic weather types--the Hudson Bay High, Northwest Canadian High, Pacific High, and Bermuda High types--the Pacific High had the greatest number of days of high fire danger (table 7). April and May showed the greatest frequency of high fire danger days (table 8).

The Hudson Bay High Type

High fire danger days associated with the Hudson Bay High type occur most frequently during the spring months. The air mass stagnates or moves slowly in the vicinity of Hudson Bay. Hudson Bay usually remains ice-covered until about mid-May and is favorable as a source region for dry polar continental air. The air mass begins its movement southward or southeastward as a high pressure area when the flow aloft becomes meridional in a position favorable for steering the High in this direction. During its movement southward the air mass warms up and subsides. The area of high fire danger is usually on the northwest side of the High although there are cases when the preceding cold front is dry and high fire danger is found in the post-frontal area and the southern quadrant.

Table 6.--Number of days with fire load index 17 and above, by station, Lake States region, 1951-60

Year	International Falls			Eau Claire			Madison			Chicago		
	17	22	37	17	22	37	17	22	37	17	22	37
1951	0	0	0	2	0	0	1	0	0	1	0	0
1952	8	6	2	1	0	0	12	6	0	0	0	0
1953	4	3	1	8	4	1	17	8	2	8	7	1
1954	3	0	0	6	3	0	7	2	0	3	2	1
1955	6	3	0	4	1	0	13	4	0	9	5	1
1956	4	1	0	7	2	0	11	7	0	14	7	0
1957	7	4	0	4	1	0	3	1	0	1	1	0
1958	7	3	0	6	1	0	13	6	0	4	4	0
1959	4	2	0	7	4	0	2	1	0	7	4	2
1960	2	1	0	2	1	1	0	0	0	3	1	0
Total	45	23	3	47	17	2	79	35	2	50	31	5

Year	Sault Ste Marie			Traverse City			Grand Rapids			Detroit		
	17	22	37	17	22	37	17	22	37	17	22	37
1951	1	1	0	2	2	0	0	0	0	0	0	0
1952	0	0	0	5	3	1	3	0	0	7	6	1
1953	0	0	0	7	3	1	12	5	0	5	3	0
1954	0	0	0	3	2	0	2	0	0	4	1	0
1955	0	0	0	1	0	0	4	1	1	4	1	0
1956	0	0	0	1	1	0	3	0	0	2	1	0
1957	0	0	0	3	1	0	2	2	0	1	0	0
1958	0	0	0	4	3	0	5	4	0	4	2	0
1959	0	0	0	3	0	0	7	1	0	0	0	0
1960	0	0	0	0	0	0	2	0	0	2	0	0
Total	1	1	0	29	15	2	40	13	1	29	14	1

Table 7.--Number of days with fire load index 17 and above, by synoptic type, Lake States region, 1951-60

Year	Hudson Bay High	Northwest Canadian High	Pacific High	Bermuda High
1951	1	3	0	0
1952	8	3	18	1
1953	11	1	23	0
1954	1	4	13	3
1955	3	0	18	3
1956	4	4	14	5
1957	8	2	2	0
1958	10	3	15	1
1959	9	1	9	1
1960	4	0	4	1
Total	59	21	116	15
Percent	28	10	55	7

Table 8.--Number of days with fire load index 17 and above by month and synoptic type, Lake States region, 1951-60

Type	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Hudson Bay High	0	0	0	13	25	3	0	9	7	2	0	0
Northwest Canadian High	0	0	0	3	11	0	1	1	5	0	0	0
Pacific High	0	0	0	28	23	16	11	4	15	15	4	0
Bermuda High	0	0	0	0	2	5	0	3	5	0	0	0
Total	0	0	0	44	61	24	12	17	32	17	4	0

The duration of the influence of the Hudson Bay High on the fire danger at a station varied from 1 to 7 days, and averaged slightly over 3 days. Two unusually long cases, where the influence of the High lasted up to 15 days were not considered normal for the type and were not included in any average or range figures. Both of these occurred with blocking patterns aloft.

The Hudson Bay High associated with the high fire danger of May 12-14, 1958 may be considered typical (fig. 25). The High dominated the weather for 3 days at International Falls and Madison and for 4 days at Chicago. Fire load indexes ranged from 17 to 31.

The development of the meridional northwest flow aloft that initially started the High on its southeasterly movement across the Lake States region may be seen on the 500 mb charts. This flow is quite characteristic of the type. Nearly all of the Hudson Bay High cases had northwesterly or northerly flow aloft in the initial stages. In this case the High started its southeastward movement as the flow aloft changed from zonal to meridional. At the termination of this type a strong short-wave trough aloft moved a cold front across the region.

As the High moved southeastward, high fire danger occurred in the southern quadrant of the High, also on the northwest side and particularly in the warm sector area. As mentioned previously, high fire danger is usually found on the north or northwest side of the Hudson Bay High. This was true in about two-thirds of the cases. The warm sector of the following low pressure system (including some pre-frontal areas) was the next most favored area for high fire danger.

A large area can experience high fire danger on the same day in the northwest portion of the High. As an example, on May 7, 1957 Eau Claire, Madison, Chicago, Traverse City, Grand Rapids, and Detroit all had high fire danger on the same day.

Most commonly, the break in high fire danger comes with the passage of a cold front. However, the breaks are about as frequently due to advection of moisture, or increased relative humidity, or the relaxing of the pressure gradient. In other cases the breaks were due to precipitation or the advection of colder air. In the May 12-14, 1958, case, the break at International Falls and Chicago was attributed to the cold front passage, whereas the break at Madison on May 13 was attributed to a relaxed pressure gradient.

Prediction.--Inasmuch as the development of high fire danger requires that the High pass across or close enough to the region to exert an influence, the first step in the prediction is the recognition of an upper flow pattern that will produce the required trajectory. For zonal cases, west to northwest flow is generally required initially.

This flow frequently changes to meridional during the type. For the more common meridional cases a ridge in the northern Rockies and a trough along or off the Atlantic coast is usually found. A plot of ridge and trough positions for the meridional cases is shown in figure 26.

As guides to the preferred positions of the High and associated Low for high fire danger in different portions of the Hudson Bay High, figures 27, 28, and 29 are presented. Figure 27 is for situations with high fire danger in the southern quadrant, figure 28 for the northern quadrant, and figure 29 for the warm sector situation. These figures also give the average intensities of the Highs and the Lows.

Table 9 shows the averages of days since rain, afternoon temperature, humidity, wind speed, and fire load index and prevailing wind direction for high fire danger days in different sections of the Hudson Bay High. These values may serve as crude guides in prediction.

The events or elements to be considered to forecast the break in high fire danger have been discussed previously.

The Northwest Canadian High Type

Periods of high fire danger associated with the Northwest Canadian High type occur less frequently than with the Hudson Bay High but they, too, are most frequent during the spring months. This type is similar to the Hudson Bay High type except that the High comes from northwest Canada instead of the Hudson Bay area and moves southeastward to the Lake States region. The polar continental (cP) air of the High may have somewhat different characteristics because of differences in the source regions during most seasons of the year.

The area of high fire danger is usually in the north and northwest portions of the High but it can occur in the post-frontal area and the southern portion. The Northwest Canadian High affected the fire danger at a station from 1 to 5 days, averaging slightly less than 2 days.

The pattern aloft with this type is usually meridional but tends to be shifted somewhat farther to the west than in the Hudson Bay High type. The northwest flow is favorable for steering the High from the source region to the Lake States.

The surface and 500 mb charts for the period September 25-29, 1952 (fig. 30) illustrate the Northwest Canadian High type. The surface High in northwest Canada began its movement southeastward on September 25 under the northwesterly flow of the meridional pattern aloft. It reached the Lake States region on September 26 and subsequently moved more eastward as the pattern aloft changed from meridional to zonal.

Table 9.--Averages of weather elements and fire load indexes for high fire danger days in portions of the Hudson Bay High, Lake States region

Portion of High	Days since rain	Temperature	Relative Humidity	Prevailing wind Direction	Prevailing wind Speed	Fire load index
		°F	Percent		Mph	
Northern quadrant	9.5	83.6	24.9	South-westerly	18.9	26.5
Post cold front	4.4	74.4	23.8	North-westerly	19.4	21.6
Southern quadrant	7.6	71.3	20.3	Variable	17.7	22.6
Warm sector	6.3	82.3	27.2	South-westerly	19.6	21.1

Table 10.--Averages of weather elements and fire load indexes for high fire danger days in portions of the Northwest Canadian High, Lake States region

Portion of High	Days since rain	Temperature	Relative Humidity	Prevailing wind Direction	Prevailing wind Speed	Fire load index
		°F	Percent		Mph	
Northern quadrant	6.1	77.2	24.1	South-westerly	18.8	25.4
Post cold front	3.5	68.4	19.7	North-westerly	22.7	24.7
Southern quadrant	12.0	80.3	26.6	South-easterly	16.6	20.6
Warm sector	4.6	81.6	25.8	South-westerly	18.8	22.8

A short-wave trough in this zonal flow and its associated low pressure system at the surface moved toward the region on September 27. High fire danger occurred in the warm sector area on September 28, particularly in Lower Michigan. The fire danger lowered as the cold front passed through the region that night.

Prediction.--The requirements for the prognosis of the Northwest Canadian High, except for noting the different geographical origin and that it results in only about 1/3 as many high fire danger days, are similar to those for the Hudson Bay High.

A plot of the ridge and trough positions for the meridional cases of this type (fig. 31) gives a guide to the required initial flow. It shows a trough to the east, which on the average is at about the same latitude as for the Hudson Bay High type. This trough is centered inland over eastern United States and the corresponding ridge is centered farther west and north in northwestern Canada.

The resulting surface pressure patterns are very similar to the Hudson Bay High type. Figures 32, 33, 34, and 35 show the positions of the High and associated Low for high fire danger in different portions of the Northwest Canadian High. Figure 32 is for the southern quadrant of the High, figure 33 for the northern quadrant, figure 34 for the warm sector area, and figure 35 for the post-cold-frontal area. Average values of central pressure are also shown.

The average values of the pertinent weather elements and fire load index, and the prevailing wind direction for high fire danger days in different parts of the Northwest Canadian High are shown in table 10.

Lowering of the fire danger may be expected with relaxation of the gradient in the post-frontal and south quadrant areas, and with the frontal passage or an increase in humidity, cloudiness, or precipitation in the warm sector and north quadrant areas.

The Pacific High Type

The Pacific High type was associated with more days of high fire danger than all others combined. A total of 116 days, or 55 percent of the high fire danger days occurred with this type.

The Pacific High type that affects the Lake States is one in which a portion of the Pacific high pressure cell penetrates the northwestern states or British Columbia, breaks off, and moves either eastward--or eastward and then southeastward.

The area of high fire danger is the post-cold-frontal area in about half of the cases. Most of the other cases are in either the northern quadrant or the warm sector, and the High tends to take a more southerly course in these cases. Very few cases of high fire danger in the Lake States in the south quadrant of the Pacific High were found, probably because the flow pattern is seldom favorable for steering a Pacific High to the north of the Great Lakes region. The duration of the influence of the High on fire danger with this type ranged from one to six days with the average slightly less than two days.

The flow pattern aloft is usually meridional with the ridge over western Canada, but the amplitude is less than with the previous two types. A higher percentage of cases is found with a zonal or short-wave train pattern aloft with Pacific Highs than with the previous two types.

The Pacific High type is illustrated by the surface and 500 mb charts for April 21-23, 1953 (fig. 36). The Pacific front which was located along the Canadian border on April 21 moved southeastward and passed through the Lake States region on April 22. In the area of strong pressure gradient behind the cold front Eau Claire had a fire load index of 24 and Madison had 27. In this area a slight anti-cyclonic curvature of the isobars may be noted. Anti-cyclonic curvature or the diverging of the surface isobars to the rear of the front is typical of this surface pattern and was noted in about two-thirds of the post-cold-front cases.

The upper-air flow pattern in this case had been meridional but changed to zonal by April 22. A series of strong short-wave troughs on April 23 changed the flow to a short-wave train pattern. Fire danger decreased on April 23 as the pressure gradient weakened.

Prediction.--In anticipating the Pacific High type in the Lake States the upper-air pattern should be considered first. This must be, or must be changed to, a pattern favorable for steering a High from the Pacific to the Lake States region. In the case of a zonal or short-wave train pattern, the High follows an easterly course to the region. With a meridional pattern the High moves first eastward or northeastward and then turns southeastward toward the region, which means that the ridge aloft is located in western Canada and the trough in north-central or northeastern United States. A few exceptions to these locations of the ridge and trough were found (fig. 37) and, of course, the path of the surface High was different in these cases. The mean ridge and trough positions for the Pacific High type are shown in figure 37.

The positions of the Highs and Lows and their average values for high fire danger in different parts of the Pacific High are shown in figures 38 to 40. Figure 38 is for the northern quadrant cases, figure 39 for the warm sector cases, and figure 40 for the post-cold-front cases.

Table 11 provides crude forecasting guides by presenting the average values of several weather elements and fire load indexes, and the prevailing wind direction for high fire danger days in different parts of the Pacific High.

In addition to the usual indications to consider in predicting the end of a high fire danger period, such as weakening of the pressure gradient, precipitation, or the advection of moisture, one other indication must be looked for in the case of post-frontal periods associated with the Pacific High. This is the passage of a Canadian front which brings in much colder air, or simply the advection of colder air where the front itself is diffuse or absent.

The Bermuda High Type

The Bermuda High was associated with fewer days of high fire danger than any other type. Only 77 of the cases were Bermuda Highs, and these were found only in the period from May through September. The period of influence of the High on the fire danger ranged from 1 to 4 days and averaged slightly less than 2 days. The Lake States region is somewhat on the fringe of the area affected by the Bermuda High. This location may be the reason for fewer cases and shorter periods of high fire danger than elsewhere--in the Southeast region, for example.

The Bermuda High type is characterized by a westward extension of the surface subtropical Bermuda High well into the country, frequently as far as Texas and the southern Great Plains. The belt of westerlies aloft and the storm track at the surface are far north over northern United States or southern Canada. The subtropical High aloft may be closed over southeastern United States.

This pattern can result in long rainless periods and high temperatures over broad areas, but the highest fire danger is found in the warm sector or pre-frontal area of an approaching system, or in the area of increased pressure gradient associated with troughs passing across the north side of the surface High.

The period August 20-22, 1955 (fig. 41) is a Bermuda High case. The Bermuda High extended westward to Texas and dominated the weather over most of the country from the Plains eastward. August 20 a Low moved eastward across southern Canada and brought the Lake States region into the warm sector. Madison had a fire load index of 34 on that day; the next day Madison again had 34, Chicago 24, and Grand Rapids 21.

The short-wave trough associated with the Low was vigorous enough so that the surface Pacific cold front could penetrate the Bermuda High. Fire danger in the Lake States lowered with the frontal passage.

Table 11.--Averages of weather elements and fire load indexes for high fire danger days in portions of the Pacific High, Lake States region

Portion of High	Days since rain	Temperature	Relative Humidity	Prevailing wind Direction	Prevailing wind speed	Fire load index
		°F	Percent		Mph	
Northern quadrant	5.3	80.2	22.2	South-westerly	17.7	23.5
Post cold front	5.7	77.2	24.5	Westerly	21.2	22.8
Southern quadrant	9.0	80.6	29.6	North-westerly	20.0	22.3
Warm sector	6.5	83.5	25.9	South-westerly	18.8	23.9

Table 12.--Averages of weather elements and fire load indexes for high fire danger days in portions of the Bermuda High, Lake States region

Portion of High	Days since rain	Temperature	Relative Humidity	Prevailing wind Direction	Prevailing wind speed	Fire load index
		°F	Percent		Mph	
Northern quadrant	5.5	94.3	29.7	South-westerly	15.3	21.2
Warm sector	9.2	93.9	27.3	South-westerly	21.5	25.4

Prediction.--The Bermuda High type is a rather sluggish type. To forecast the peaks of fire danger it is necessary to predict the development and movement of short-wave troughs aloft and the associated surface systems. The flow aloft must allow the surface system to be steered into a position such that the region will be affected by a steepening pressure gradient. The end of the high fire danger period is brought about by a frontal passage, a weakening of the pressure gradient, precipitation, or increased moisture.

Figure 42 indicates the ridge and trough positions for meridional cases of the Bermuda High type. The ridge is far north and over the continent in all cases. Figure 43 shows the positions of High and Low centers for days of high fire danger and the average pressures of the centers. In all cases the danger was found in either the warm sector or the northern quadrant. Average values of the pertinent weather variables and fire load index, and the prevailing wind direction for these cases are shown in Table 12.

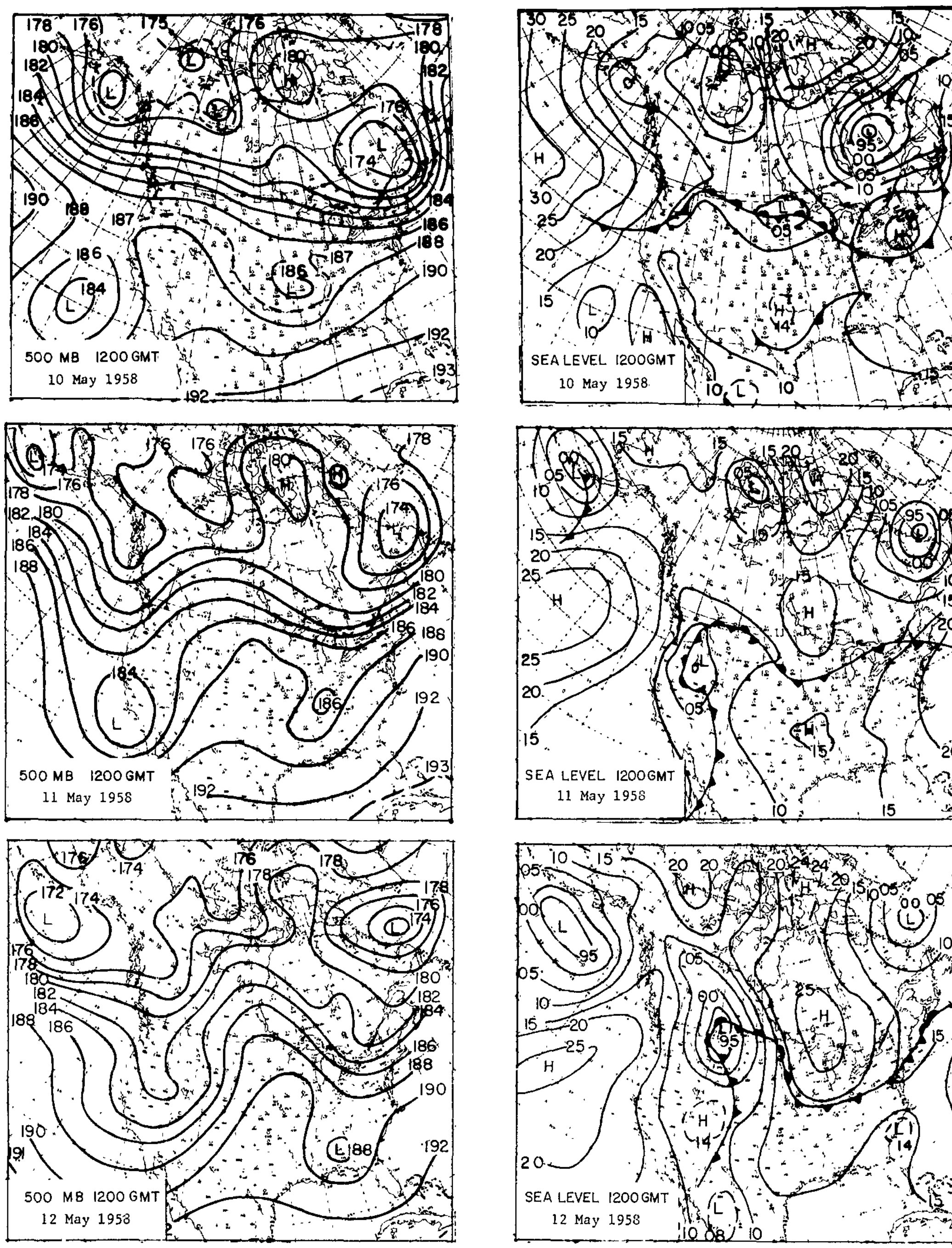


Figure 25. --Surface and 500 mb charts, May 10-15, 1958. High fire danger occurred on the south and west sides of the High and in the warm sector area May 12-14.

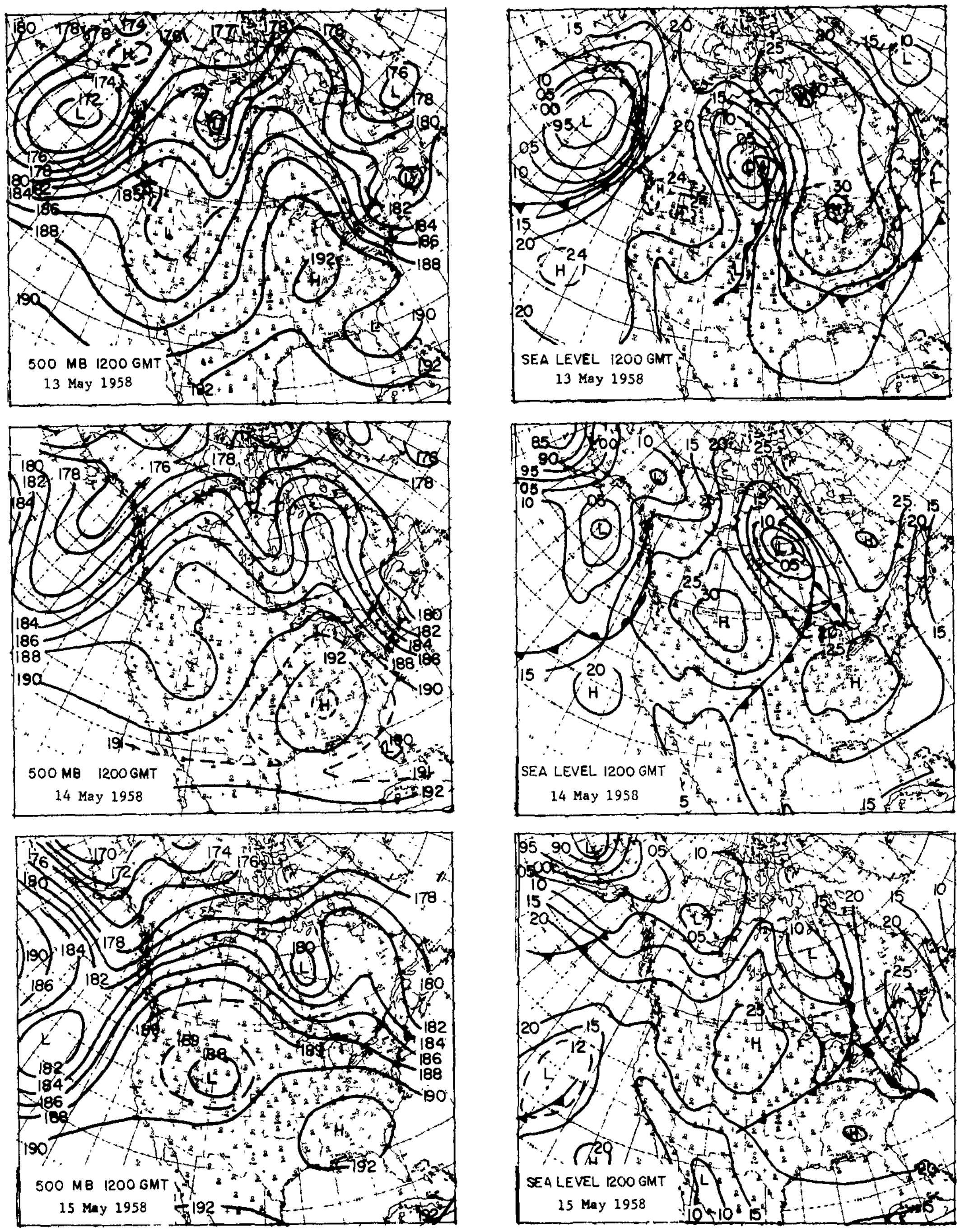


Figure 25. --Continued.

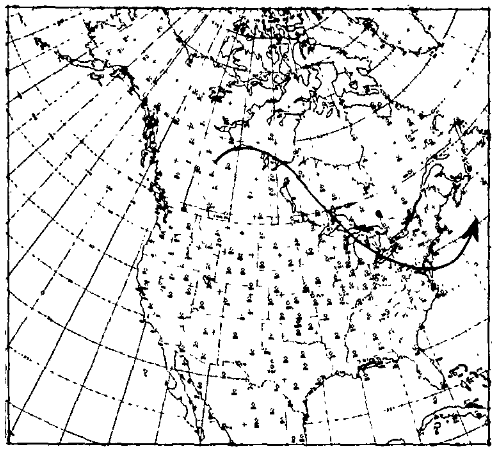


Figure 26. --Mean 500 mb ridge and trough positions for meridional cases of Hudson Bay Highs.

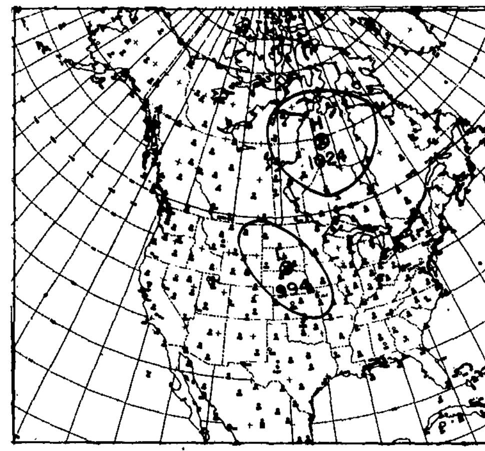


Figure 27. --Mean position and intensity of High and Low centers for Hudson Bay High cases with high fire danger in southern quadrant. In two-thirds of the cases the centers fell within the areas indicated.

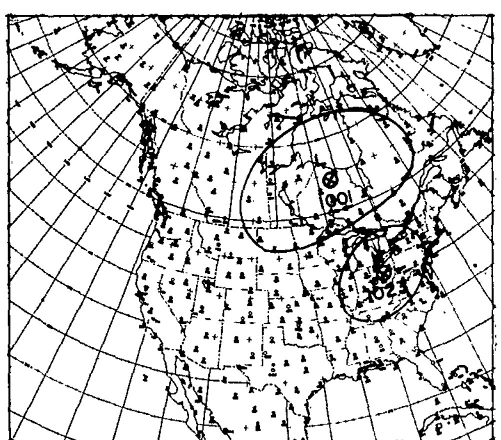


Figure 28. --Mean position and intensity of High and Low centers for Hudson Bay High cases with high fire danger in northern quadrant. In two-thirds of the cases the centers fell within the areas indicated.

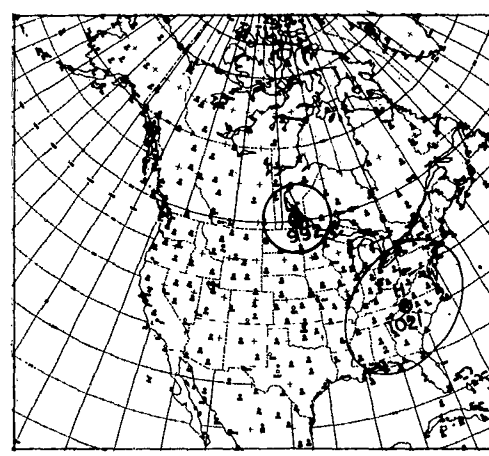


Figure 29. --Mean position and intensity of High and Low centers for Hudson Bay High cases with high fire danger in the warm sector. The centers fell within the areas indicated in two-thirds of the cases.

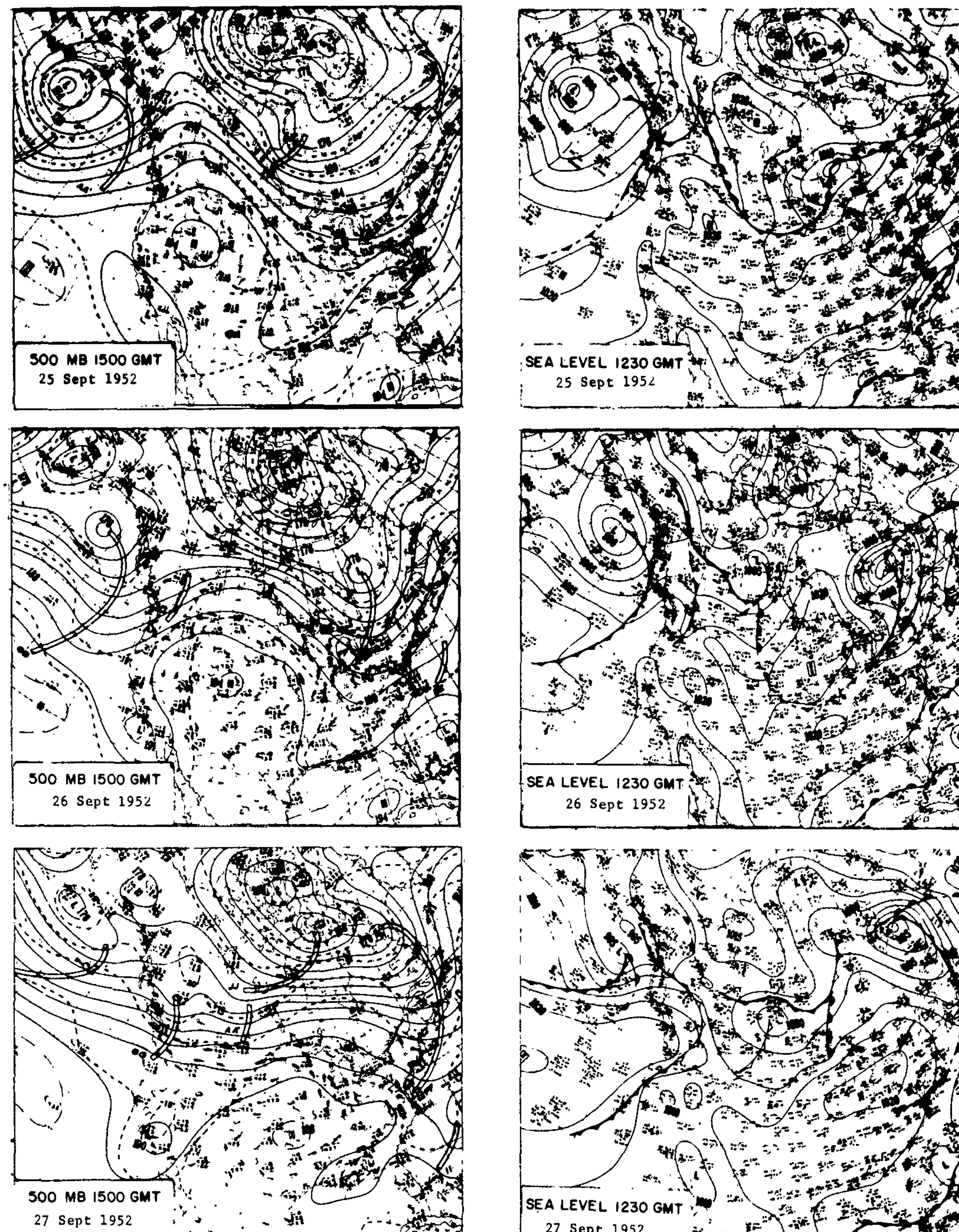


Figure 30. --Surface and 500 mb charts, September 25-29, 1952. High fire danger occurred September 28 on the northwest side of the High.

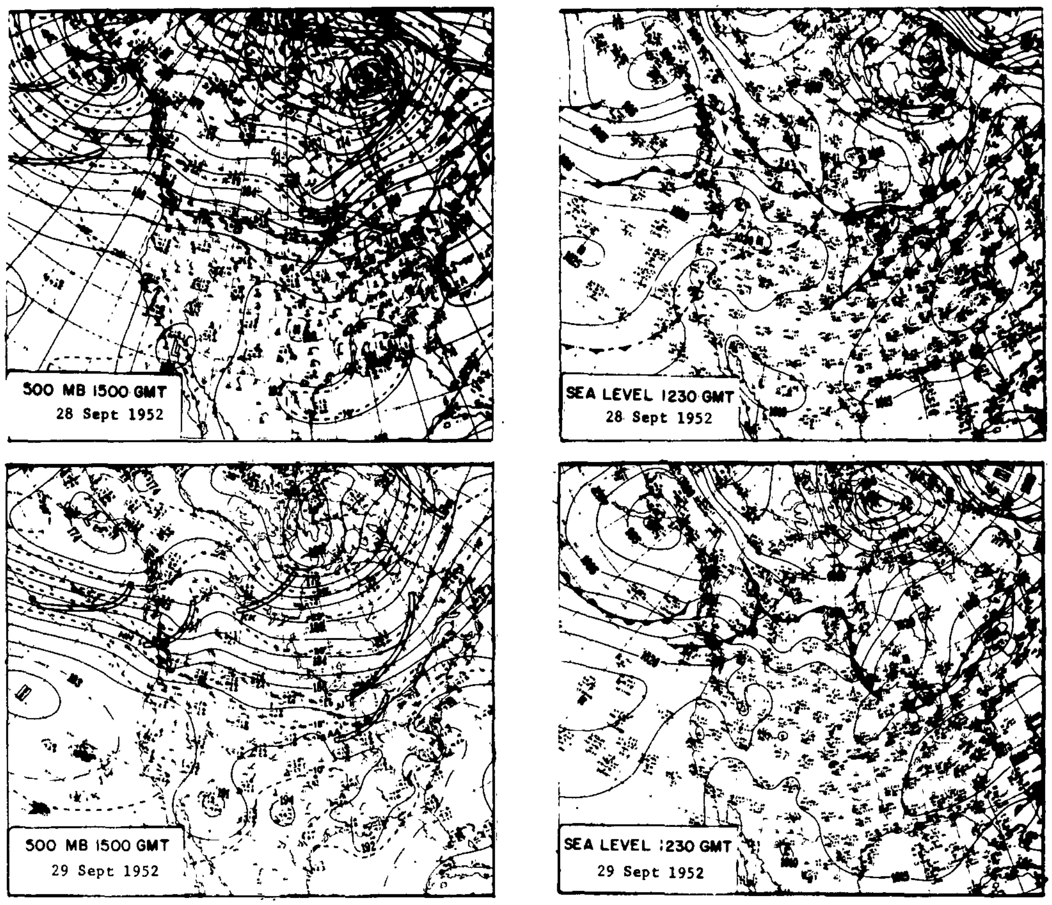


Figure 30. --Continued.

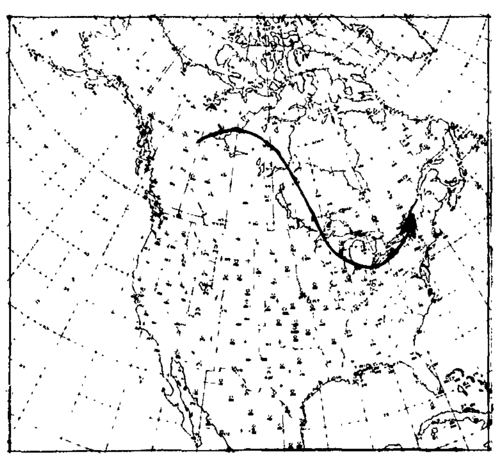


Figure 31. --Mean 500 mb ridge and trough positions for meridional cases of Northwest Canadian Highs.

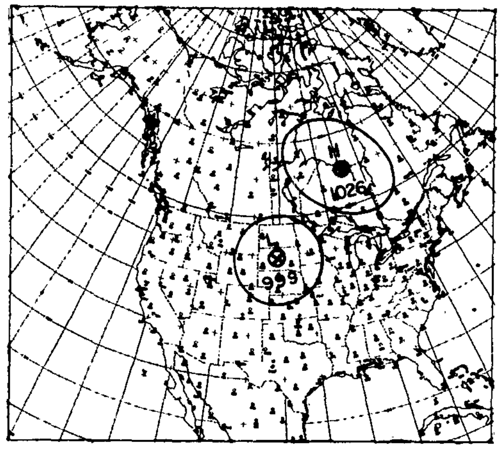


Figure 32. --Mean position and intensity of High and Low centers for Northwest Canadian High cases with high fire danger in the southern quadrant. There were only four cases and all of the centers fell within the areas indicated.

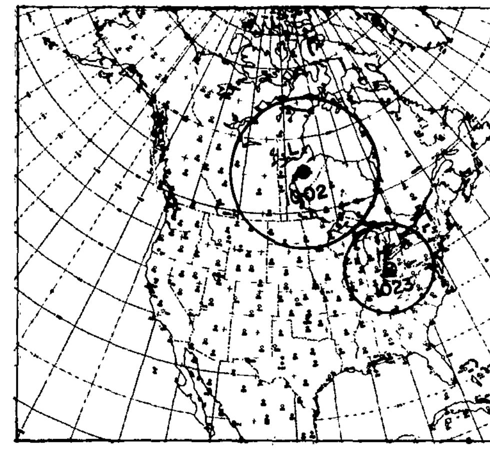


Figure 33. --Same as figure 32 for high fire danger in northern quadrant. There were six cases and all centers fell within the areas indicated.

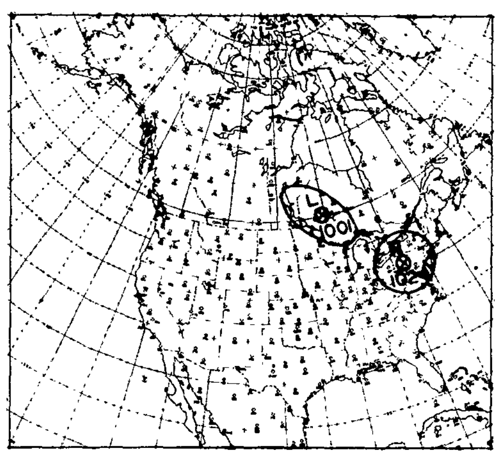


Figure 34. --Same as figure 32 for high fire danger in the warm sector. In three out of a total of four cases the centers fell within the areas indicated.

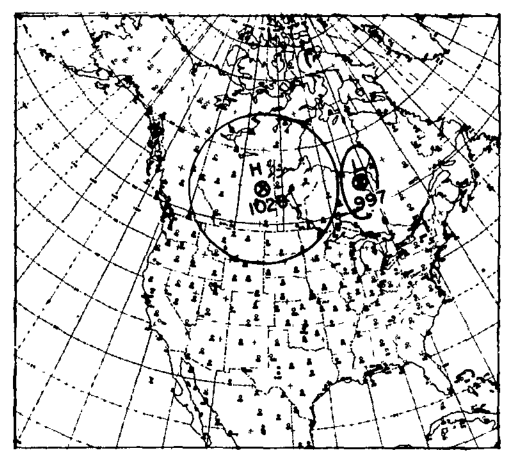


Figure 35. --Same as figure 32 for high fire danger in post-frontal areas. There were five cases and all of the centers fell within the areas indicated.

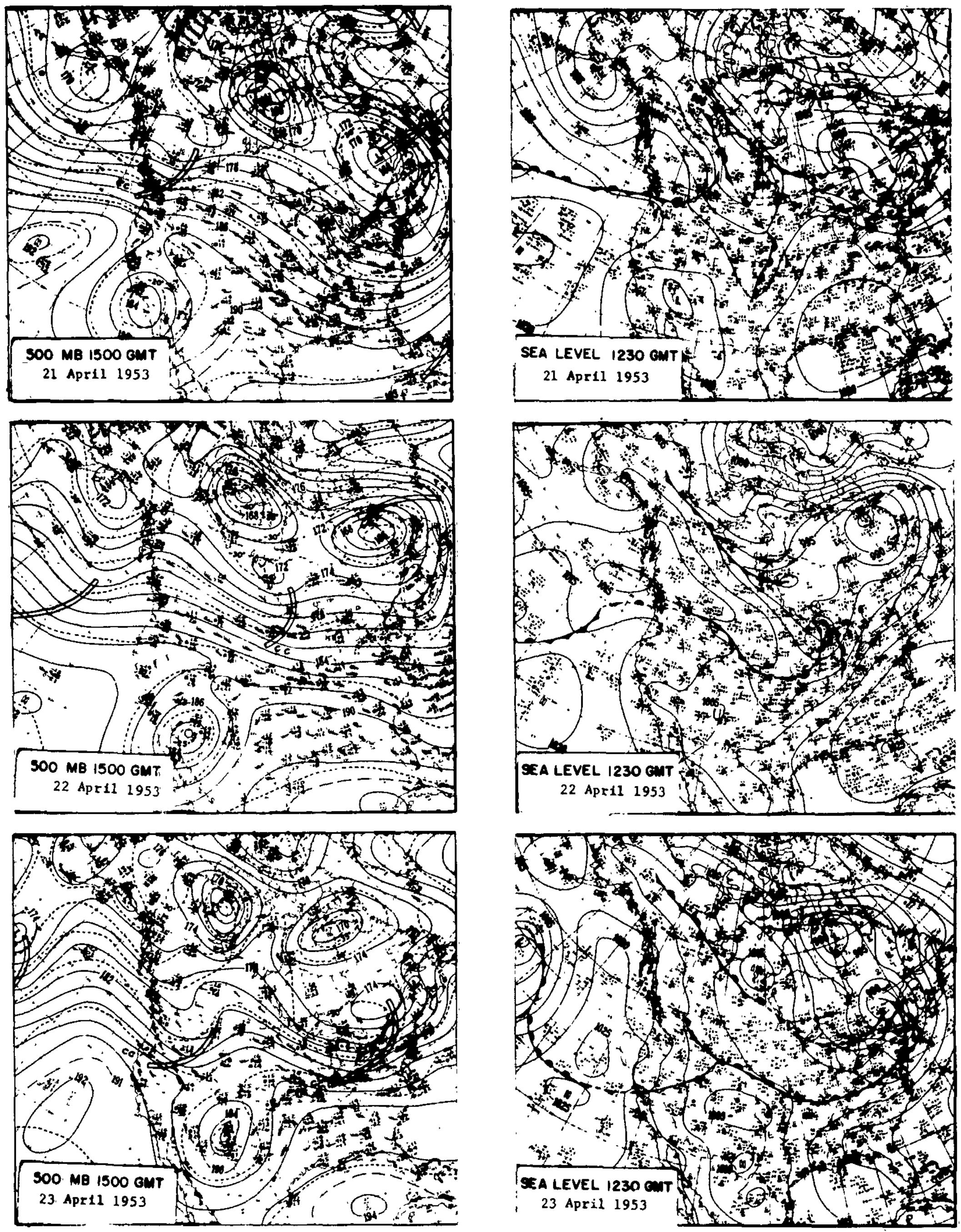


Figure 36 -Surface and 500 mb charts, April 21-23, 1953. High fire danger occurred to the rear of the Pacific front on April 22.

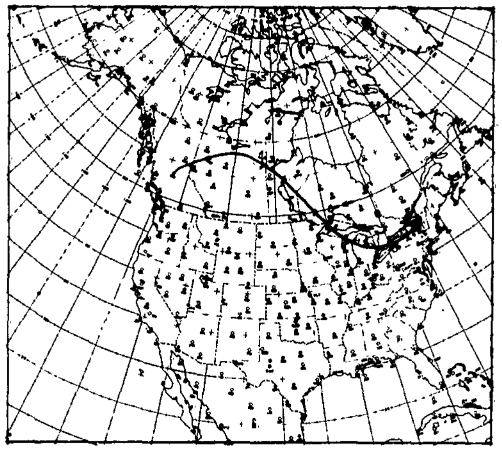


Figure 37. --Mean 500 mb ridge and trough positions for meridional cases of Pacific Highs.

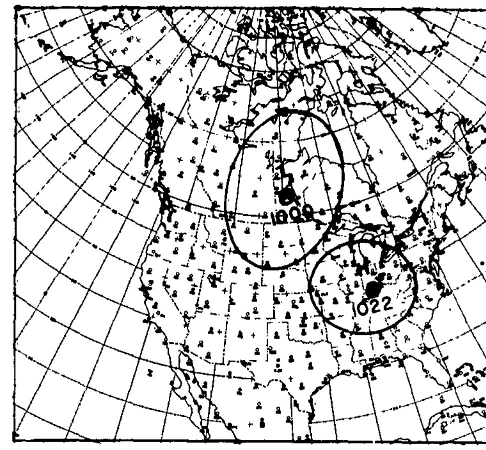


Figure 38. --Mean position and intensity of High and Low centers for Pacific High cases with high fire danger in the northern quadrant. In four-fifths of the cases the centers fell within the areas indicated.

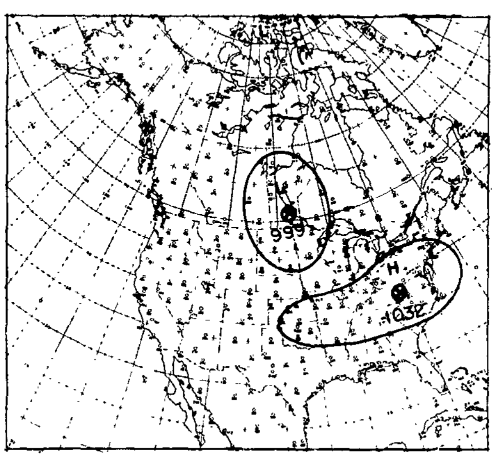


Figure 39. --Same as figure 38 for high fire danger in the warm sector. The centers fell within the areas indicated in two-thirds of the cases.

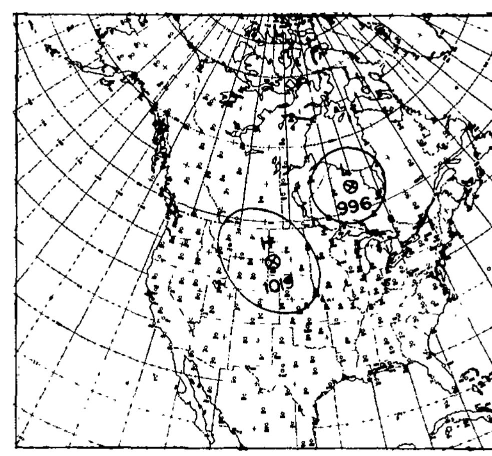


Figure 40. --Same as figure 38 for high fire danger in the post-frontal area. In two-thirds of the cases the centers fell within the areas indicated.

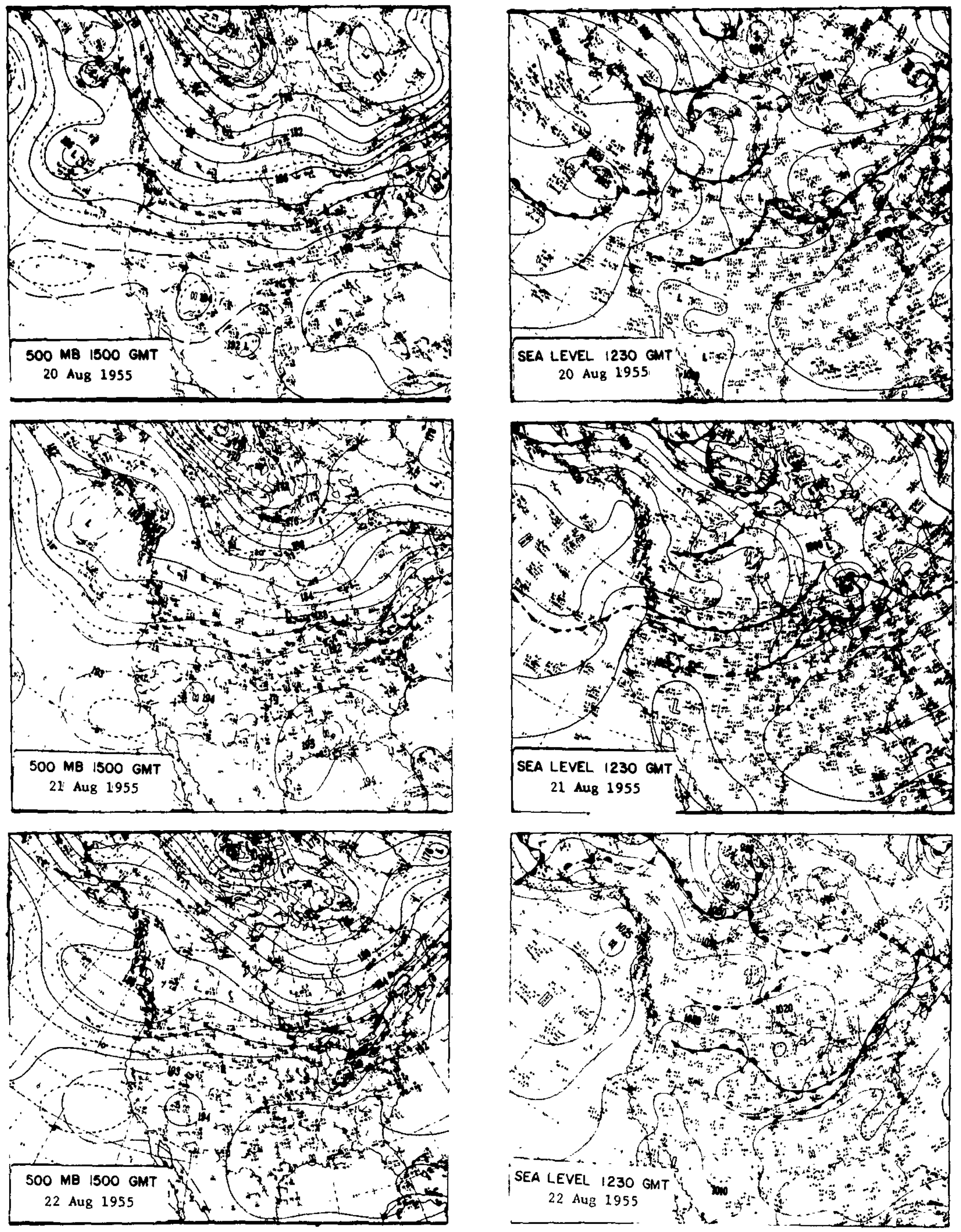


Figure 41. --Surface and 500 mb charts, August 20-22, 1955.

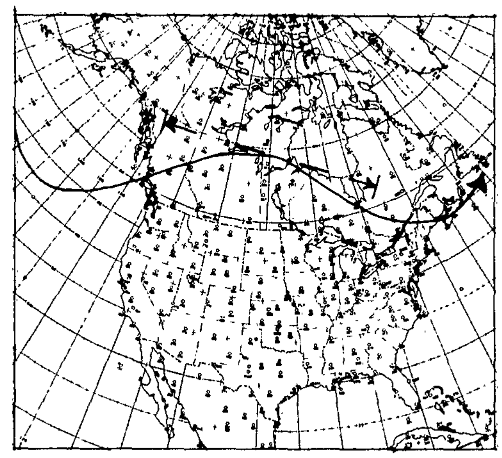


Figure 42. --Mean 500 mb ridge and trough positions for meridional cases of the Bermuda High type. The longitudinal range of the ridge position is indicated.

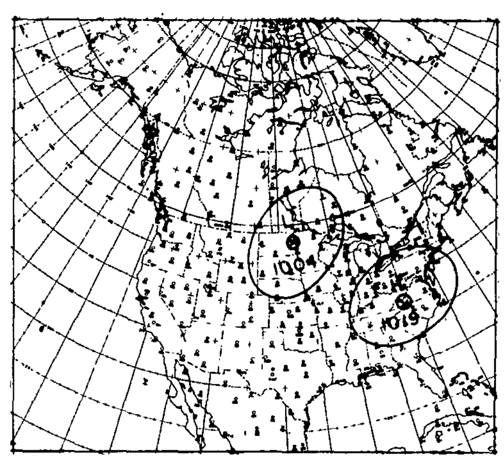
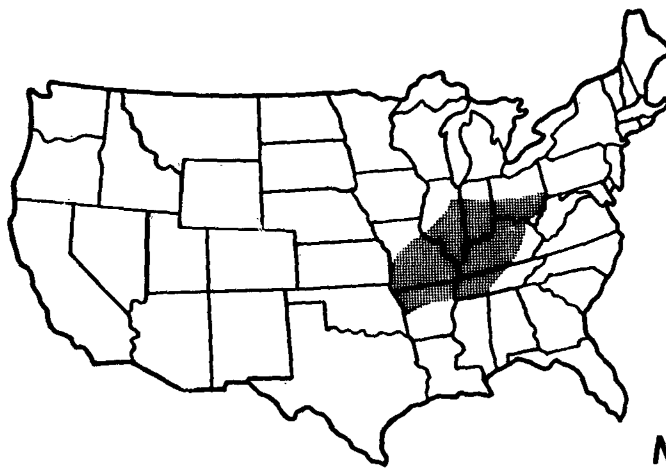


Figure 43. --Mean position and intensity of High and Low centers for Bermuda High cases. The high fire danger was either in the warm sector area or the northern quadrant. In four-fifths of the cases the centers fell within the areas indicated.



Ohio and Middle Mississippi Valleys Region

The Ohio and Middle Mississippi valley region includes the area from west of the Appalachians in southern Ohio, Kentucky, and Tennessee westward to the Ozarks of Missouri and Arkansas. As to fire weather, this region is a transition area between the Gulf States to the south and the Lake States to the north. Depending upon the broadscale flow pattern, it will at times experience fire weather similar to the interior of the Gulf States, and at other times be under the influence of air masses and pressure patterns that also affect the Lake States.

The stations used to represent this region were Columbus, Ohio, Evansville, Ind., Lexington, Ky., St. Louis and Springfield, Mo., and Memphis, Tenn.

The period of high fire danger usually extends from March through November, but in some years the southern part of the region may also experience high fire danger during the winter months. The fire load index which is exceeded about 1 percent of the time during the March through November period runs from 14 at Columbus to 20 at St. Louis and Evansville, 22 at Memphis and Lexington, and 30 at Springfield. In this region cases were selected for investigation which had fire load indexes of 17 or higher at any station. A fire load index of 17 or higher in March through November occurs less than 1 percent of the time at Columbus to 6.8 percent at Springfield. The average for the 6 stations in the region is slightly over 3 percent of the time. (Further information on the frequency of occurrences of specific values of fire load index may be found in Appendix A.)

High fire danger is most frequent in spring (April and May) and fall (September). The occurrence of large wildfires also shows spring and fall maxima. The fire danger follows the seasonal trends of the broadscale upper-air pattern.

The thermal contrast between the continent and the oceans works toward ridging of the belt of westerlies in the summer and troughing in the winter, and tends to develop a warm High over the central Plains during midsummer. The ridge tends to shift westward towards southwest Canada in the fall and to northwest United States in the spring just as the strongest band of westerlies shifts southward in the winter and northward in the summer.

At the surface, migrating Pacific high pressure systems can be expected during the period of maximum zonal flow in March. The zonal flow tends to buckle and become more meridional as it begins to decrease in April, and occasional blocking patterns appear. The Bermuda High begins to extend farther westward into the continent. This sets the stage for more frequent intrusions of Northwest Canadian and Hudson Bay high pressure systems which reinforce the westward extension of the Bermuda High. Subsequent frontal systems tend to stall and develop waves in the southern Great Plains.

Although warm, moist air tends to be dominant in the spring, the occasional intrusion of dry polar air masses and strong pressure gradients in warm sectors preceding the subsequent frontal system produces the spring maximum of high fire danger. The most frequent sequence of events in these situations is for southwest winds to increase as the surface pressure falls and the cold front approaches. The cold front then tends to stall and develop a warm sector. Surface winds increase to 25-30 mph, temperatures rise to about 10 degrees above seasonal normal, relative humidity falls to about 25 percent as moisture is mixed upward and drier air mixed downward, and the fire load index climbs to about 25. Such a situation, however, has a decidedly short life span. Owing to the proximity of the Gulf of Mexico, moisture soon is carried northward, raising the humidity and lowering the fire danger sharply. In fact, the fire danger remains high for only one day on the average and generally drops before precipitation occurs, the cold front passes, or winds decrease.

Except for a few widely scattered periods of unusually high wind and temperature, summer periods of high fire danger appear to be confined to drought years. In drought periods the circulation is weak and temperatures aloft are generally abnormally high. High fire danger during drought years can be quite frequent and prolonged, occurring readily in either pre-frontal or post-frontal areas. Three of the 10 years of the study fall into the category of drought years: 1952, 1953, and 1954.

In fall, the fire danger reaches its peak in September and continues high through October and into November as westerlies increase. With rare exceptions there is a sharp and quite final fall-off in fire danger after the middle of the month. The fall season differs considerably from the spring season in that the flow aloft is more meridional.

High pressure systems move southeastward readily from the northwest Canadian area and from Hudson Bay and have little difficulty plunging through to the Gulf of Mexico since the Bermuda High extension is generally absent. Typically, these high pressure areas may remain pronounced as they reach the northeastern United States and retain a ridge extension southwestward to Texas. This high pressure ridge into Texas serves to ward off Gulf moisture in the fall season. In its normal spring position the Bermuda extension is conducive to rapid transport of moisture northward from the Gulf of Mexico. In spring the high fire danger tends to occur in the pre-frontal or warm sector area. In fall both pre-frontal and post-frontal situations can be expected. Fall is normally the driest season of the year and has the greatest number of days of high fire danger.

Only infrequent days of high fire danger can be expected during the winter months. These occur when surface temperatures rise to 10 degrees or more above the seasonal normal, southwest winds hit 15 to 30 mph, and relative humidity 20 percent or lower. This situation breaks up quickly with increased humidity or cold front passage.

The synoptic weather types associated with high fire danger in this region are the same as for other regions east of the Rocky Mountains, i.e., the Hudson Bay High, Northwest Canadian High, Pacific High, and Bermuda High. The distribution and frequency of associated high fire danger are listed in tables 13 and 14.

The Pacific High Type

In this region the Pacific High type accounted for 18 percent of the cases and 14 percent of days of high fire danger and tended to occur mostly in early spring and in fall. The duration of high fire danger with this type is very short because the High generally moves rapidly in a zonal or meridional pattern of small amplitude aloft. Frequently the high fire danger lasts only one day, seldom more than two days.

The surface and 500 mb charts for April 2-5, 1959 (fig. 44) illustrate this type. On April 2 the 500 mb pattern across the northern Pacific and on into western United States was quite zonal. A short-wave trough associated with the surface frontal system in the Dakotas had entered the Pacific Northwest. Behind this system a breakoff of the Pacific anticyclone was entering northwestern United States and southwestern Canada.

The entire system moved quite rapidly, the Pacific High beginning to influence the region on April 3. The short-wave trough aloft deepened considerably as it reached eastern United States. High fire danger appeared in the western part of the region on April 4 on the northwest side of the Pacific High, which had reached the Gulf States.

Table 13.--Number of cases and number of days with fire load index 17 and above by synoptic type and year, Ohio and Middle Mississippi valleys, 1951-60

Year	Hudson Bay High	Northwest Canadian High	Pacific High	Bermuda High	Total
1951					
Cases	5	9	0	1	15
Days	5	10	0	1	16
1952					
Cases	8	7	9	5	29
Days	12	12	14	12	50
1953					
Cases	24	5	6	1	36
Days	64	10	7	2	83
1954					
Cases	10	9	0	4	23
Days	30	16	0	9	55
1955					
Cases	3	8	0	3	14
Days	6	22	0	7	35
1956					
Cases	9	8	8	4	29
Days	18	14	14	9	55
1957					
Cases	2	1	2	2	7
Days	6	1	2	2	11
1958					
Cases	2	2	0	0	4
Days	2	2	0	0	4
1959					
Cases	5	4	6	0	15
Days	7	4	9	0	20
1960					
Cases	2	6	3	2	13
Days	4	6	3	3	16
Total					
Cases	70	59	34	22	185
Days	154	97	49	45	345
Percent					
Cases	38	32	18	12	--
Days	45	28	14	13	--

Table 14.--Number of cases and number of days with fire load index 17 and above by synoptic type and month, Ohio and Middle Mississippi valleys, 1951-60

Month	Hudson Bay High	Northwest Canadian High	Pacific High	Bermuda High	Total
January					
Cases	0	3	1	0	4
Days	0	3	1	0	4
February					
Cases	0	1	1	0	2
Days	0	1	1	0	2
March					
Cases	3	4	7	0	14
Days	6	4	10	0	20
April					
Cases	4	12	3	5	24
Days	9	13	5	14	41
May					
Cases	13	3	1	1	18
Days	17	4	1	2	24
June					
Cases	8	0	0	7	15
Days	17	0	0	15	32
July					
Cases	7	1	6	3	17
Days	14	1	9	7	31
August					
Cases	12	3	1	6	22
Days	33	6	1	7	47
September					
Cases	14	14	4	0	32
Days	38	36	8	0	82
October					
Cases	8	10	4	0	22
Days	19	18	4	0	41
November					
Cases	1	6	6	0	13
Days	1	9	9	0	19
December					
Cases	0	2	0	0	2
Days	0	2	0	0	2

High fire danger spread to the eastern part of the region on April 5 as the entire region came under the influence of a strong pressure gradient in the warm sector of a cyclone passing to the north.

Fire danger was reduced the next day as the pressure gradient decreased and the region came under the influence of a cooler air mass.

The Northwest Canadian High Type

The Northwest Canadian High type, occurring mostly in spring and fall and infrequently in summer and winter, accounted for 32 percent of the high fire danger cases and 28 percent of the days. The duration of the period of high fire danger averaged only one day in spring, when the general circulation is still fairly strong, and 2 to 3 days in fall, when movement of systems is much slower. The flow pattern aloft is usually meridional with this type, and the ridge is far to the west, in western Canada or the Gulf of Alaska. The northwest flow is favorable for steering the High from its source region to the central part of the United States.

The Northwest Canadian High type is illustrated by the surface and 500 mb charts for the period September 9-14, 1955 (fig. 45). On September 9 the flow pattern aloft was favorable for moving the High in northwest Canada southeastward. The fire danger in the Ohio and middle Mississippi valleys and, incidentally, northward into the southern Lake States, was very high on September 9 in the warm sector on the western side of the High centered over New England. This also was a Northwest Canadian High.

September 10-12 the High from northwest Canada moved southeastward to the Ohio Valley. September 13 it took an east-northeastward course as the flow aloft over the United States became more zonal. High fire danger occurred at individual stations during this period when the region was on the southern side of the High.

September 13 a warm sector developed over the western Plains. As it moved eastward September 14, most of the region experienced high fire danger. The ridge extension southwestward from the High center, cutting off Gulf moisture, is typical.

Only temporary relief from high fire danger was experienced as the pressure gradient relaxed in this case since a Hudson Bay High type followed.

The Hudson Bay High Type

The Hudson Bay High type produced more high fire danger cases and days in this region than any other type. Thirty-eight percent of the cases and 45 percent of the days were associated with this type. In the Lake States and the Southeast region most of the Hudson Bay High cases appeared in spring.

In this region, although there was a spring maximum, most of the cases occurred in late summer and early fall. The average length of each period was 2 to 3 days.

As with the Northwest Canadian High type, the flow pattern aloft is nearly always meridional. The ridge position is in central Canada.

In the case of July 9-12, 1954 (fig. 46) the High moved from Hudson Bay south-southeastward to the eastern Great Lakes and North Atlantic States, and then became extended southwestward. An alternate pattern is one in which the High travels a course farther to the west, moving down through the Great Plains and western Great Lakes region and then moving eastward through the middle Mississippi and Ohio valleys.

On July 9 the position of the meridional ridge was favorable for a south-southeastward movement of the High leaving the Hudson Bay region. As the High continued southward the air mass became warmer and drier through heating and subsidence. The fire load indexes gradually rose in the region, becoming high on July 12.

The persistent high-level anticyclone which is characteristic of this and other drought years in the East was evident in the central United States throughout the July 9-12 case. It prevented the Hudson Bay High from taking a more westerly course.

Whether the high fire danger in the middle Mississippi valley was due to the dry air brought down from Hudson Bay or to the warmth and dryness characteristically found beneath the high level anticyclone is open to question. In any event, there was no let-up in fire danger as the Hudson Bay High moved northeastward on July 13 because a Bermuda High type followed it.

In most Hudson Bay High cases the critical area to watch is the warm sector or pre-frontal area on the northwest side of the High.

The Bermuda High Type

The Bermuda High type is mostly a summer or early fall phenomenon but can occur in late spring also. During drought years it can appear at repeated intervals involving weeks and produce fire load indexes up to the 90's. This type accounted for 12 percent of the high fire danger cases and 13 percent of the days during the 10-year period. Average duration of the high fire danger period was 2 to 3 days.

The Bermuda High type that followed the July 9-12 Hudson Bay High is illustrated by the surface and 500 mb charts for July 13-14, 1954 (fig. 47).

The anticyclone over central United States on the 500 mb chart kept the belt of westerlies and the track of cyclones far to the north along the Canadian border. At the surface, following the passage of a tropical storm northward along the Atlantic Coast, an extension of the Bermuda High penetrated westward through the Gulf States as far as Texas. The lack of precipitation and the abnormally high temperatures and low humidities characteristic of subsidence in the deep anticyclone set the stage for critical fire weather. Only increased wind was needed. This occurs as pressure gradients increase with the passage of frontal systems to the north. Such a frontal system passed to the north of the region on July 13 and 14, producing fire load indexes as high as 40 at Springfield July 13, and 34 at Lexington July 14.

Again, no lasting relief from high fire danger occurred. This Bermuda High was followed by a Northwest Canadian High type. In other Bermuda High cases the fire danger lowers because of relaxed pressure gradient, the advection of Gulf moisture, or the passage of a cold front bringing a colder air mass over the region.

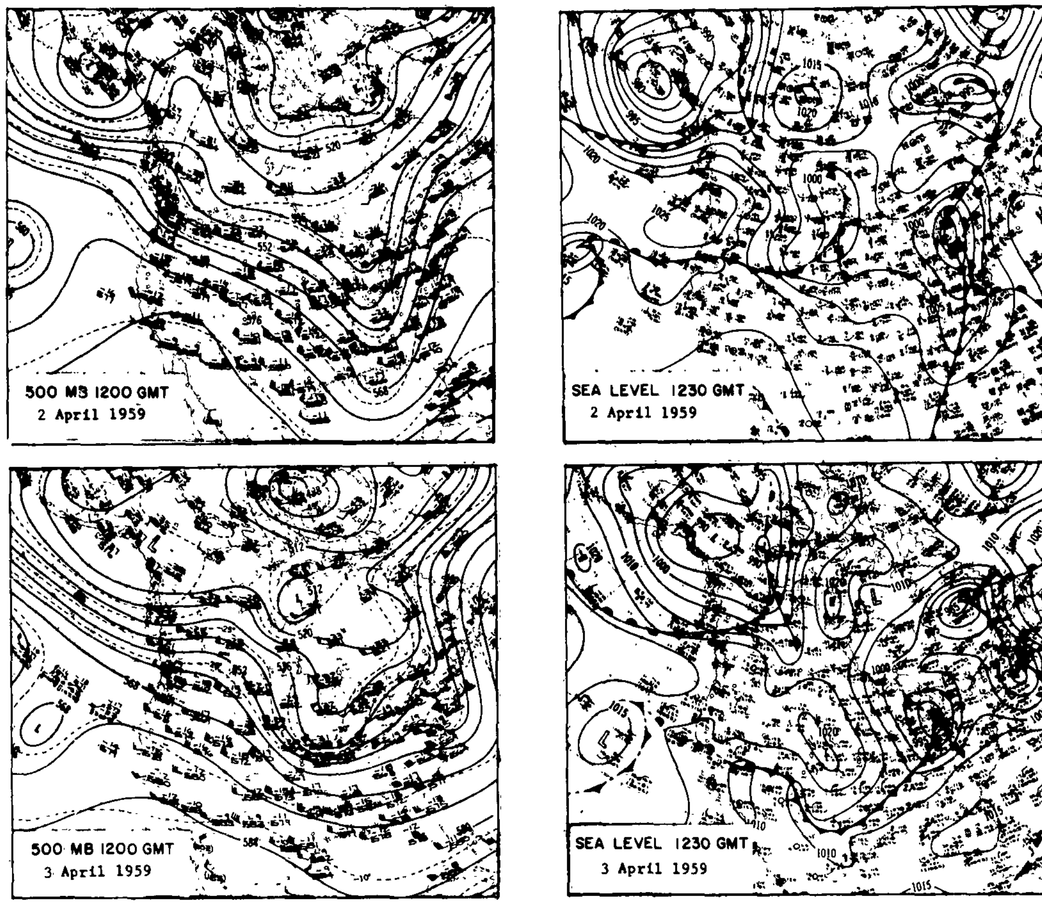


Figure 44. --Surface and 500 mb charts, April 2-5, 1959. On April 4 Springfield, Mo., had a fire load index of 29 and on April 5 Lexington had 20.

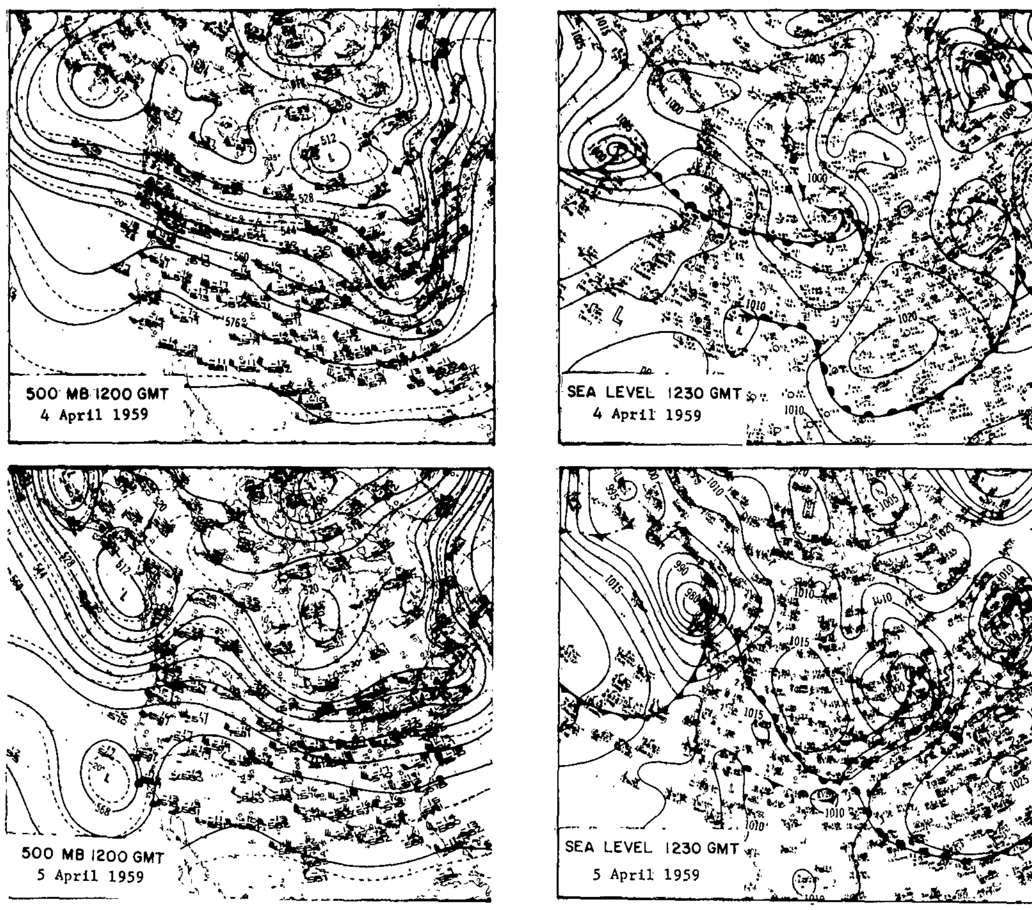


Figure 44. --Continued.

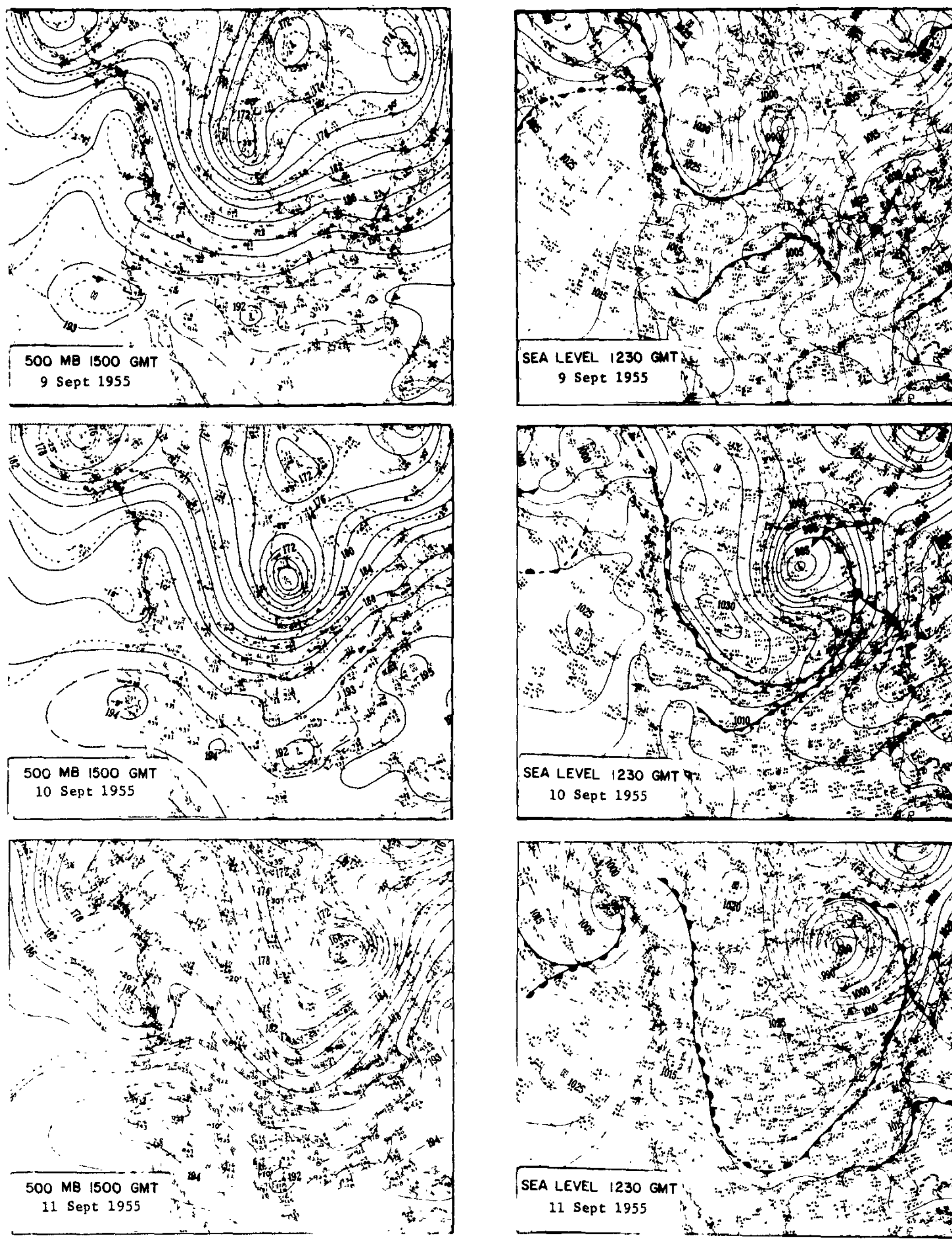


Figure 45.--Surface and 500 mb charts, September 9-14, 1955. Highest fire danger occurred in the warm sector area September 14.

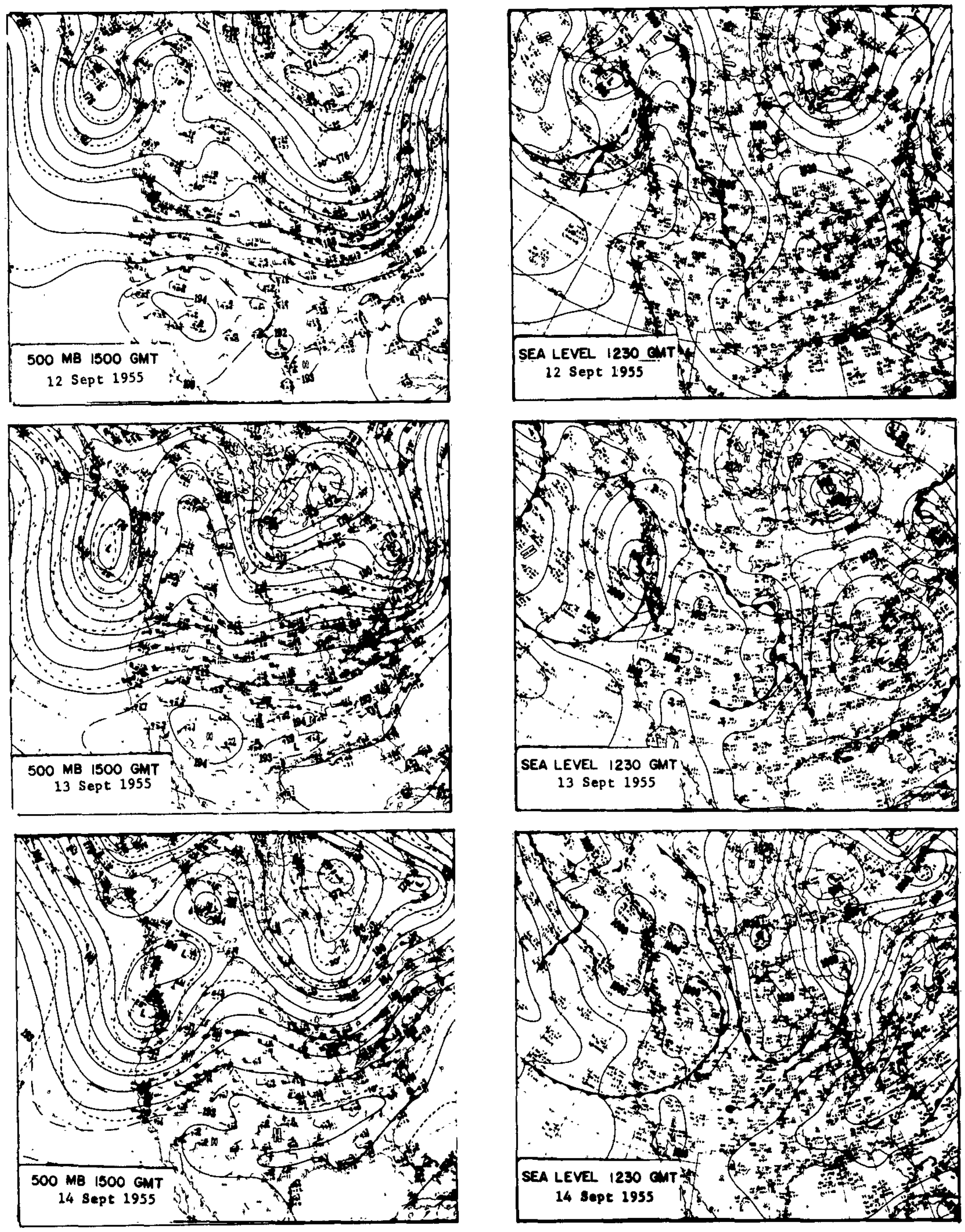


Figure 45. --Continued.

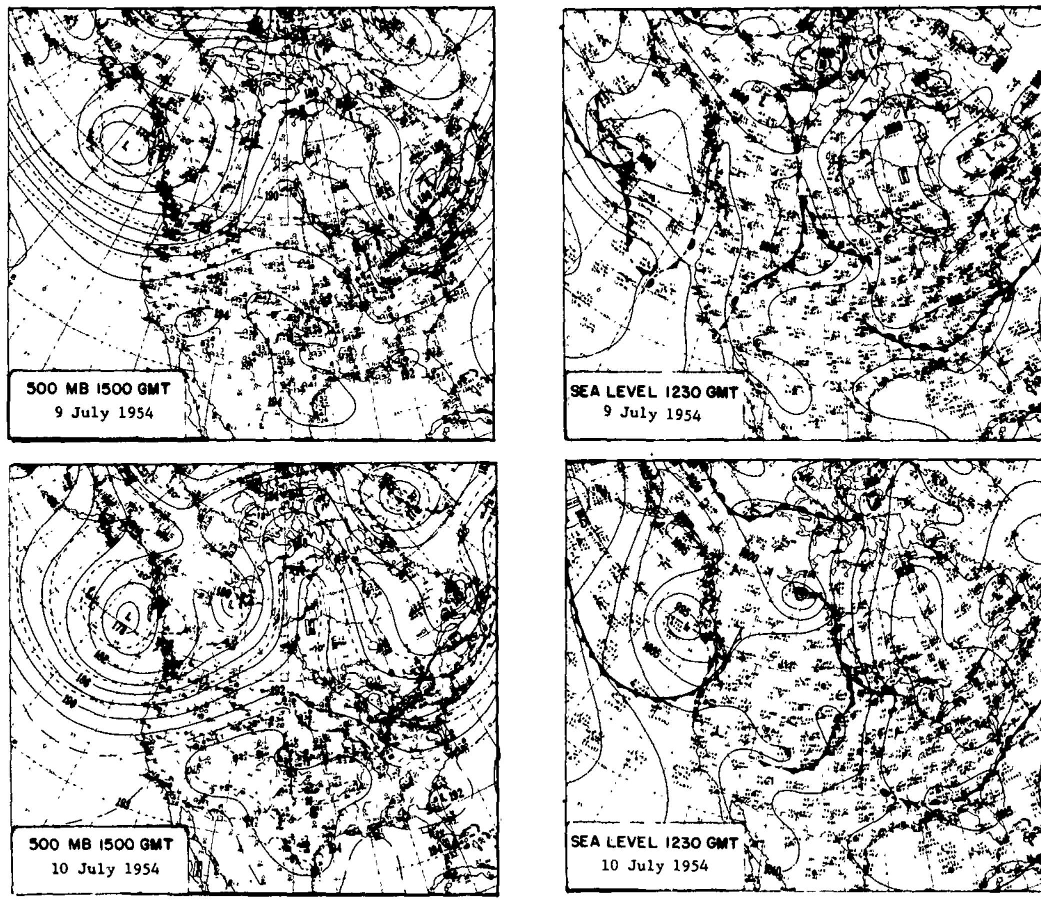


Figure 46. --Surface and 500 mb charts, July 9-12, 1954. High fire danger occurred in the pre-frontal area July 12.

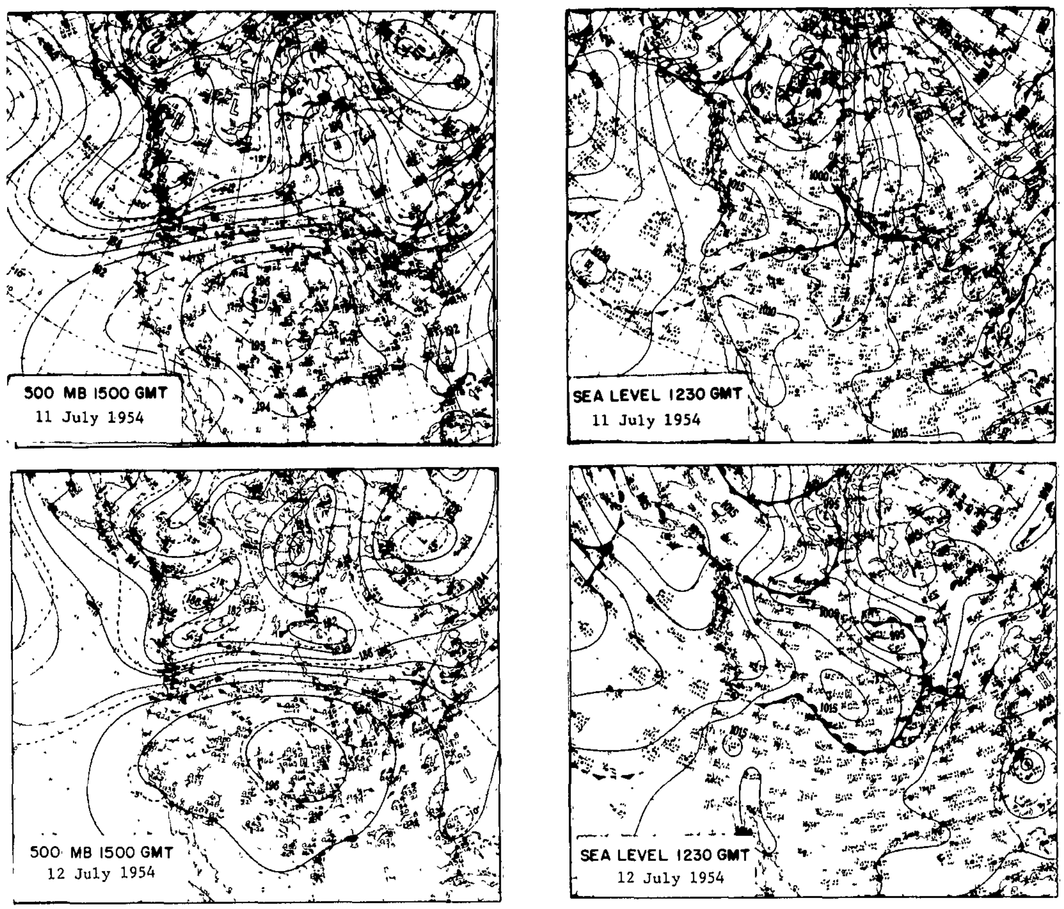


Figure 46. --Continued.

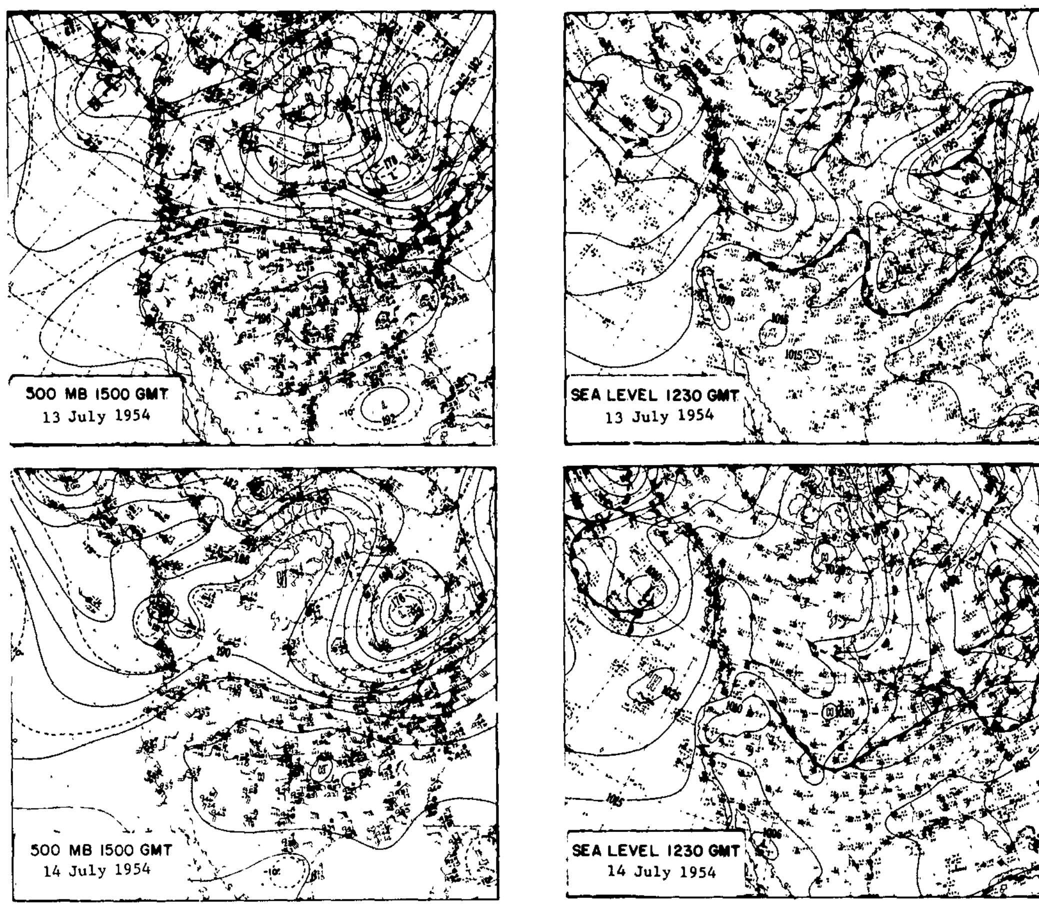
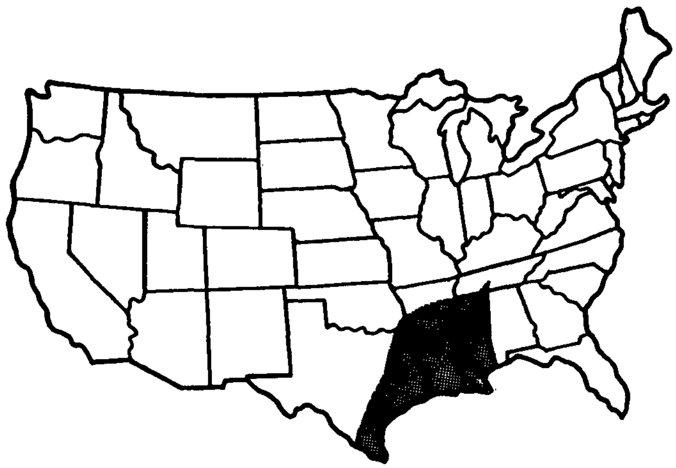


Figure 47.--Surface and 500 mb charts, July 13-14, 1954. High fire danger occurred both days.



West Gulf States Region

The West Gulf States include Mississippi, Louisiana, southern Arkansas, and the eastern portion of Texas. The weather stations used to rate this region are Jackson, Miss., Shreveport, La., Little Rock, Ark., and Houston, Tex. This region is affected by Gulf air, but stations along the Gulf coast were intentionally avoided in this study because of the pronounced effect of Gulf moisture and the resulting low fire danger.

The climate in most of this region can be classified as humid, and the western edge as sub-humid since it borders the drier climate characteristic of areas further to the west. Average annual precipitation ranges from 45 inches at Houston and Shreveport to 47 at Little Rock and nearly 51 at Jackson. The winter and spring months are usually the wettest and the fall months are the driest. Some areas have a secondary maximum of precipitation in July, apparently due to thunderstorm activity. The winter and spring rains are mostly due to low pressure areas of the Texas, Colorado, or south Pacific type. On the average, about 100 days a year have precipitation of 0.01 or more inches.

August through October are normally the most critical months of fire weather. Next are the spring months of March, April, and May. During these five months a fire load index of 17 or higher (the basis for selecting study cases) occurs about 2 percent of the time. Nearly half of the 24 days with a fire load index of 17 or higher appeared in August, September, and October (table 15). The spring months had about a quarter of the days.

Table 15.--Number of days with fire load index 17 and above, West Gulf States, 1951-60

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1951	1	0	1	4	7	2	0	6	1	0	0	0	22
1952	1	2	2	0	4	3	3	3	7	15	2	0	42
1953	0	0	0	5	1	6	3	3	12	4	6	0	40
1954	0	9	6	1	0	1	5	15	15	1	1	1	55
1955	0	0	3	4	2	0	0	0	2	9	4	0	24
1956	2	1	1	1	0	0	4	6	9	3	3	1	31
1957	0	0	0	2	0	0	0	0	0	0	0	0	2
1958	1	0	1	3	0	0	1	0	1	1	1	0	9
1959	0	0	1	0	2	0	0	0	0	1	2	0	6
1960	0	0	2	4	2	2	0	0	0	0	0	0	10
Total	5	12	17	24	18	14	16	33	47	34	19	2	241

Table 16.--Number of days with fire load index 17 and above, by station and year, West Gulf States, 1951-60

Year	Little Rock			Jackson			Shreveport			Houston		
	Fire load index equal to or greater than--											
	17	22	37	17	22	37	17	22	37	17	22	37
1951	6	0	0	10	4	0	8	3	1	5	3	0
1952	14	6	1	13	9	0	11	7	1	18	7	1
1953	14	8	0	14	4	0	7	3	0	12	3	1
1954	30	19	1	10	5	0	15	4	1	16	11	2
1955	3	2	0	9	4	1	6	2	0	13	5	0
1956	13	5	1	4	3	1	21	8	3	6	3	1
1957	1	0	0	0	0	0	1	0	0	1	0	0
1958	2	1	1	1	1	0	5	3	2	5	3	1
1959	3	0	0	0	0	0	4	2	1	1	1	0
1960	1	0	0	1	0	0	5	4	0	5	2	1
Total	87	41	4	62	30	2	83	36	9	82	38	7

Table 17.--Number of cases and number of days with fire load index 17 and above by month and synoptic type, West Gulf States, 1951-60

Month	Northwest Canadian High	Pacific High	Bermuda High	Hudson Bay High	Tropical Storm	Total
January						
Cases	2	3	0	0	0	5
Days	2	3	0	0	0	5
February						
Cases	1	6	0	0	0	7
Days	2	10	0	0	0	12
March						
Cases	5	5	1	2	0	13
Days	5	8	1	3	0	17
April						
Cases	4	13	0	1	0	18
Days	5	17	0	2	0	24
May						
Cases	3	3	5	0	0	21
Days	4	7	7	0	0	18
June						
Cases	1	5	5	0	0	11
Days	1	6	7	0	0	14
July						
Cases	1	0	7	0	0	8
Days	1	0	15	0	0	16
August						
Cases	1	3	7	0	1	12
Days	4	4	24	0	1	33
September						
Cases	9	6	8	2	1	26
Days	15	11	15	4	2	47
October						
Cases	8	13	0	1	0	22
Days	18	17	0	1	0	36
November						
Cases	8	4	1	0	0	13
Days	9	9	1	0	0	19
December						
Cases	0	2	0	0	0	2
Days	0	2	0	0	0	2
Total						
Cases	43	63	34	6	2	148
Days	66	94	70	10	3	243
Percent of Days	27	39	29	4	1	--

Table 18.--Number of days with fire load index 17 and above, by type and area of High, West Gulf States, 1951-60

Area	Northwest Canadian High	Pacific High	Bermuda High	Hudson Bay High	Total
Post-frontal	26	47	1	4	78
Southern quadrant	38	20	0	3	61
Northern quadrant	4	15	4	2	25
Pre-frontal	17	41	81	3	142
Total	85	123	86	12	306

Beginning during the latter part of 1951 and continuing through 1956, a prolonged, widespread, and historic drought cycle prevailed in the region. In both the region as a whole (table 15) and at individual stations (table 16), the drought had a marked effect on the fire load index. Nearly nine-tenths of the days of high fire danger occurred during the period. The average number of days per year was 36 for that period, and 7 for the years 1957-1960.

Study of the surface and 500 mb charts for the days of high fire danger revealed five synoptic weather types. These were the Pacific High, Northwest Canadian High, Hudson Bay High, Bermuda High, and Tropical Storm. The Pacific High type, particularly in post-frontal and pre-frontal areas, accounted for the greatest number of days of high fire danger (tables 17 and 18).

The Pacific High Type

The Pacific High type accounted for 39 percent of the high fire danger days. This type occurs most frequently in late winter and early spring and during the fall months.

The Pacific High type begins when a portion of the east Pacific high pressure cell enters the Pacific Northwest or British Columbia and moves southeastward. In crossing the Rocky Mountains and descending on the east side, the Pacific air mass loses much of its moisture. As it enters the West Gulf States, it bathes the region in dry air and cuts off advection of moisture from the Gulf of Mexico. The area of high fire danger may be in the post-frontal area as the High moves into the region, or in the pre-frontal area on the west side of the High as the center moves off to the east and becomes merged with the Bermuda High. Occasionally, high fire danger is found in the southern

quadrant if the High passes to the north of the region and in the northern quadrant if the High moves farther south and continues to prevent Gulf moisture from invading the region.

The flow aloft with this type may vary from zonal to meridional. The ridge aloft is to the west of the region and the trough is to the east. The belt of westerlies is rather far north so that low pressure centers pass well to the north of the region. The surface Pacific High enters the country behind a short-wave trough aloft. The track that the High takes will vary with the flow pattern aloft. With zonal flow the path may be southeastward toward the region if the ridge aloft is over the western states, or southward and then eastward if the ridge is near the Pacific coast.

If the cold front in advance of the High is dry, then high fire danger may be expected in the strong gradient area behind the cold front. Since the system is a moving one, the period of high danger is usually short. As the Pacific High reaches the Atlantic coast it tends to stall and merges with the Bermuda High. At this time high fire danger may be expected in the pre-frontal area on the west side of the High or in the warm sector of approaching frontal systems. The warm sector area appears to be particularly critical.

Fire danger decreases as the High continues its eastward movement and the flow around its west side carries moisture from the Gulf of Mexico into the West Gulf States. At times a relaxing of the pressure gradient and the resultant lowering of wind speed may also be a factor.

A series of maps for April 27--May 2, 1955 illustrates the Pacific High type (fig. 48). April 27 a portion of the east Pacific high cell entered the Pacific Northwest behind a rather vigorous short-wave trough aloft. The long-wave ridge position was over the Plains and although the short-wave trough flattened the ridge temporarily, it built back up by April 29. The surface High by this time was centered over the Midwest and extended southward into the West Gulf States. The northwesterly winds aloft and the northwest to east winds at the surface effectively prevented Gulf moisture from entering the region. In such a situation the fire danger becomes high whenever the pressure gradient is strengthened and the winds increase. In this case high fire danger was reported at Houston and Jackson April 30, and at Houston again May 2. Fire danger then decreased as the circulation became favorable for bringing in Gulf moisture at low levels.

The Northwest Canadian High Type

The Northwest Canadian High type accounted for 27 percent of the days of high fire danger in the West Gulf States. This type tends to occur in the spring and fall months. It is similar to the Pacific High type, but since the air mass is of continental origin it is drier.

For a High from Northwest Canada to reach the West Gulf States, the flow aloft must be strongly meridional with the ridge located along the West Coast. Occasionally the pattern aloft is a combination meridional pattern over the Pacific Ocean and the West Coast with a ridge over Alaska, and a zonal pattern over the rest of the continent and across the Atlantic. In the latter case the High from northwest Canada plunges directly southward along the Rockies and then moves eastward across the country.

The Northwest Canadian High moves southward or southeastward from its source region and follows the passage of a short-wave trough aloft and a Canadian cold front at the surface. The air mass is dry and originally quite cool. It becomes warmed as it moves to lower latitudes by passing over a warm surface and by solar radiation. It is also warmed by subsidence. By the time it reaches the West Gulf States, the humidity is low. Dryness and strong winds around the periphery of the High produce high fire danger. Because of the direction of movement of the High, the southern quadrant as well as the eastern quadrant may be considered a post-frontal area. On more than three-fourths of the high fire danger days associated with this type, the critical area was in these two quadrants. Because of the rapid movement, however, the critical period is short. On less than one-fourth of the days, high fire danger was found in the pre-frontal area as the High center moved off to the east.

The Northwest Canadian High type is illustrated by charts for October 26-31, 1952, (fig. 49). The upper-air pattern was strongly meridional October 26, with a ridge along the west coast of Canada. A short-wave trough was moving southeastward into the Midwest. At the surface a High in northwest Canada began moving south-southeastward behind the frontal system associated with the short-wave trough. The cold front passed through the region on October 27 and brought the fire load index to 37 at Little Rock and Shreveport and to 23 at Jackson in the post-frontal area. A dry air mass covered the region in advance of the front and, as a result, the front passed without precipitation.

October 28, although the High center was still in the central Plains, the dry Canadian air covered the entire region. The fire load index was 34 at Jackson that day, 24 at Shreveport, and 40 at Houston. At Little Rock where the pressure gradient decreased, the index dropped to 6.

On subsequent days the pattern aloft changed from meridional to zonal and the High took an easterly course. Fire danger decreased first because of the lower wind velocities and then because the circulation became favorable for advecting moisture from the Gulf of Mexico into the region.

The Hudson Bay High Type

In the West Gulf States, the Hudson Bay High type is similar to the Northwest Canadian High type. It accounted for only 4 percent of the high fire danger days and will not be described in detail. All occurrences were either in spring or the fall. In the spring the air mass may be colder and drier than a Northwest Canadian air mass because on the average Hudson Bay remains frozen until mid-May.

The flow aloft with this type is strongly meridional with the ridge over central or western Canada and a trough near the east coast. The High plunges southward to the Southern Plains and then moves eastward as the flow pattern aloft becomes more zonal. This High then merges with the Bermuda High and may maintain a ridge westward across the Gulf States. Dry air will remain over the region until the circulation becomes favorable for a long enough time to advect moisture inland from the Gulf.

The charts for August 30-September 4, 1954 illustrate the Hudson Bay High type (fig. 50). August 30 the High from the Hudson Bay region was already moving southward on the east side of the meridional ridge aloft and the leading cold front began passing through the West Gulf States that day.

Fire danger became high at Jackson September 1 and 2 in the southern quadrant of the High, which was in the post-frontal area. Northeasterly flow at the surface and aloft blocked Gulf moisture. Subsequently the closed anti-cyclonic circulation aloft moved over the region, creating a subsidence situation, and the Hudson Bay High became a westward extension of the Bermuda High. Fire danger remained high at several stations through September 5 as dry air remained over the region and frontal systems passed to the north. Little Rock recorded 31 September 3 and 45 on September 4 in the warm sector. Fire danger began to decrease in coastal areas September 5 and over the entire region September 6 as the gradient weakened and moist air was brought in.

The Bermuda High Type

The Bermuda High type occurs almost exclusively during the warmer months, from May through September. It accounted for 29 percent of the high fire danger days in the West Gulf States. This type is the drought pattern for the region and much of the rest of the eastern part of the country. It is characterized by persistent high temperatures which offset to some extent the fact that the air mass is not as dry as those of polar origin.

The upper-air pattern may be zonal or meridional but most frequently it is zonal. The important characteristic of the upper-air pattern is the ridge which lies over the central portion of the continent and usually imposes a closed anti-cyclonic circulation over the southern

two-thirds of the country. The belt of westerlies is far to the north, near or north of the Canadian border, and cyclonic systems are prevented from reaching the Gulf States.

At the surface the important feature is the extension of the Bermuda High westward across the Gulf States as far as Texas. The source of moisture in the Gulf of Mexico is cut off by this pattern. Subsidence in the ridge aloft and the surface High results in clear skies, high temperatures, and low humidities. The stage is set for critical fire weather whenever wind speed increases. This occurs where the gradient tightens in the pre-frontal or warm sector area on the west or north side of the High as frontal systems pass to the north of the region.

The Bermuda High is a persistent and sometimes stagnant synoptic type. It brings about long periods without precipitation and with high temperatures. On occasion, some scattered thundershowers might develop but no widespread rain occurs. The drought is not ended until the ridge aloft is broken down and a vigorous trough aloft is allowed to pass. Often, the breakdown comes when a cold Low moves out of the Pacific and across the south portion of the country. The fire danger may decrease if the extension of the Bermuda High retreats eastward and moisture is allowed to travel around its western edge into the West Gulf States. Unless the ridge aloft breaks down, however, the relief is only temporary.

An example of the surface and upper-air patterns in the Bermuda High type is the charts for June 24, 1952 (fig. 51). The closed anti-cyclonic circulation aloft, the belt of westerlies to the north, and the extension of the Bermuda High into the Gulf States, are all evident. During an extended period with this type, details of the pattern continually vary. The ridge extension will protrude farther westward, then retreat to the east; advection of Gulf moisture will vary accordingly. On this day, the high fire danger occurred principally in the northwestern portion of the region where the gradient tightened because of the frontal system to the northwest. Little Rock reported a fire load index of 29.

The Tropical Storm Type

Only two cases of tropical storms or hurricanes causing high fire danger in the West Gulf States were recorded during the 10-year study period. They account for about 1 percent of the high fire danger days. Oncoming tropical storms may have a strong wind field associated with them which extends beyond the rain and cloud shield. High fire danger can occur in this area if the air has a land trajectory. Further discussion of this type and an example may be found in the section on the Southeast.

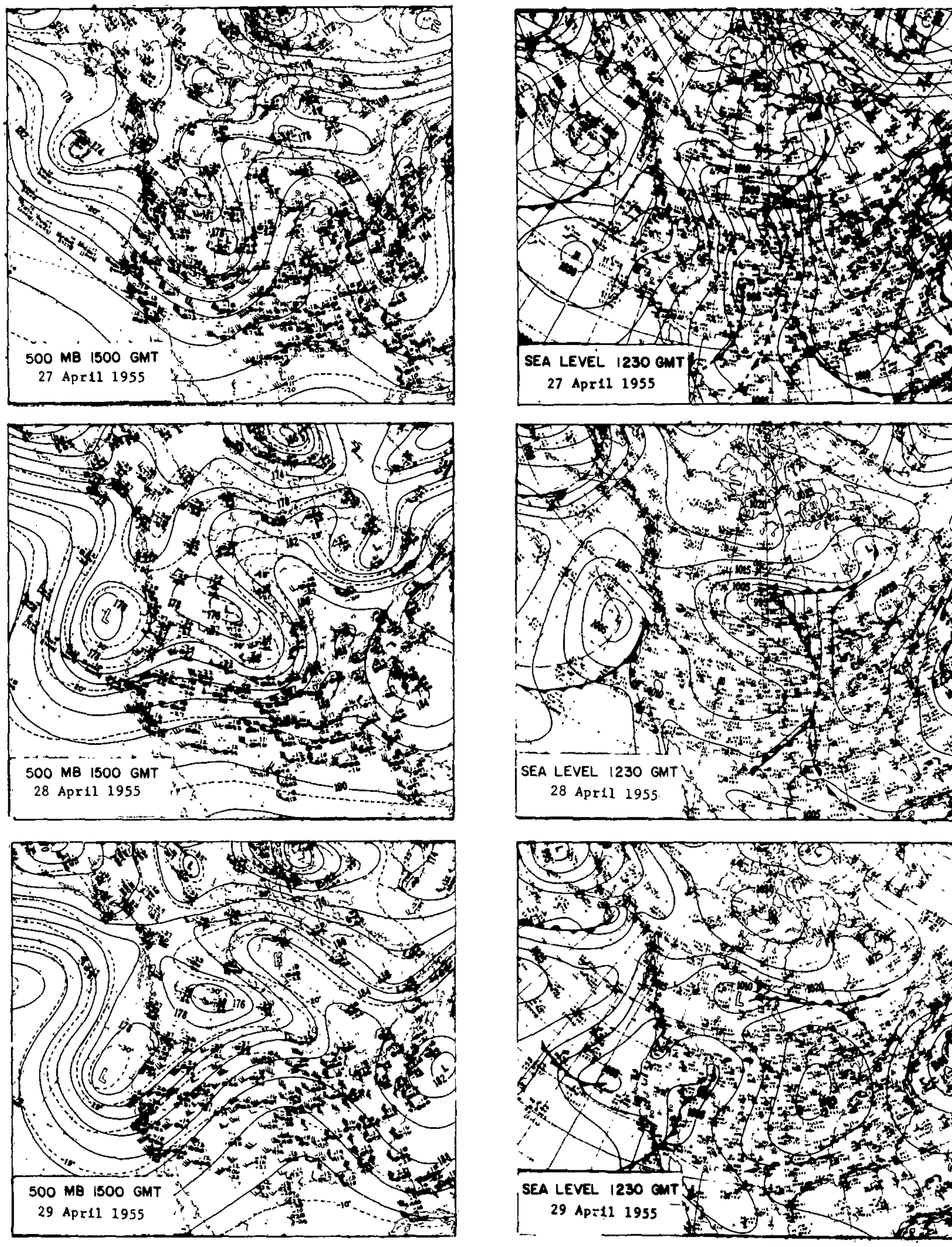


Figure 48. --Surface and 500 mb charts, April 27-May 2, 1955.

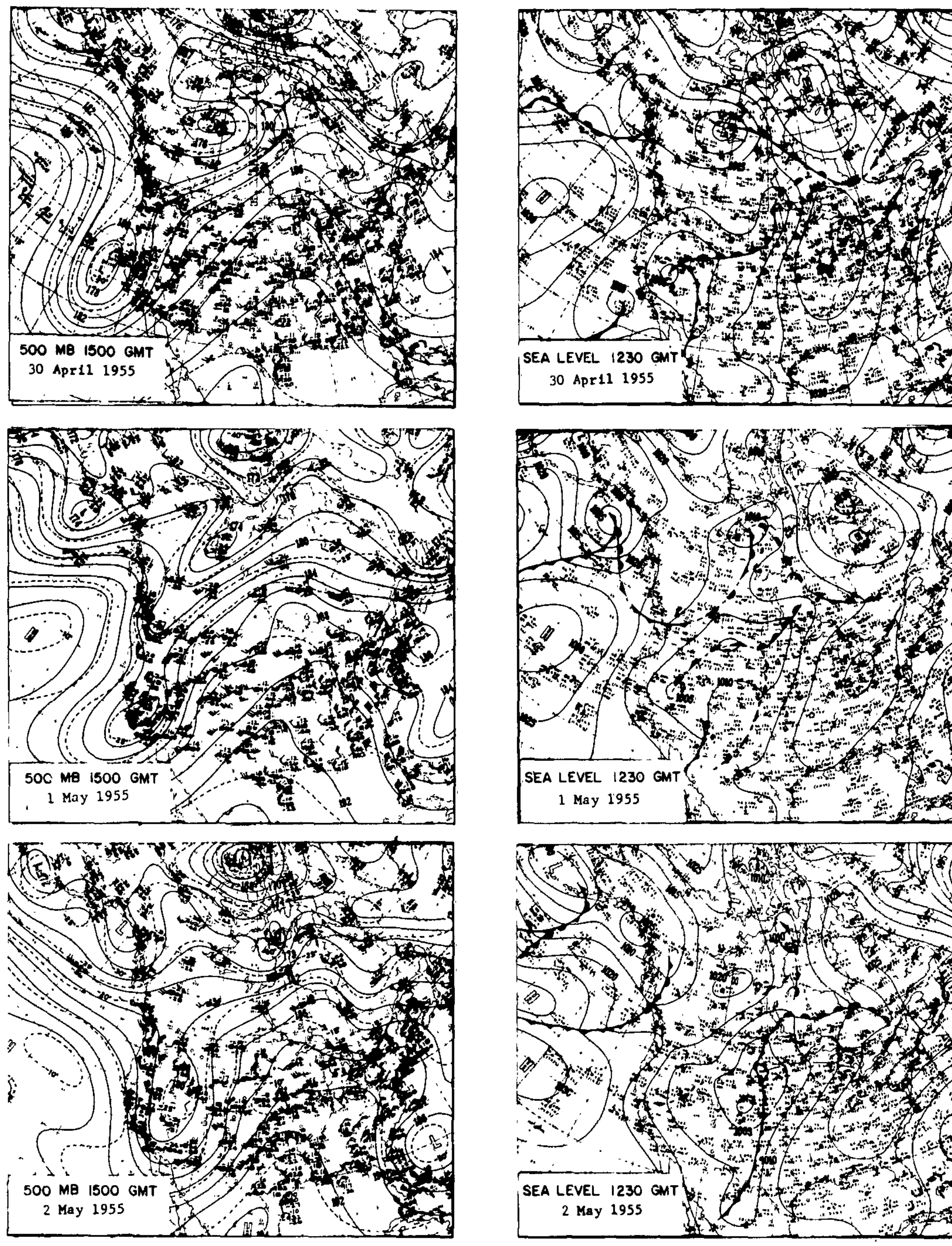


Figure 48. --Continued.

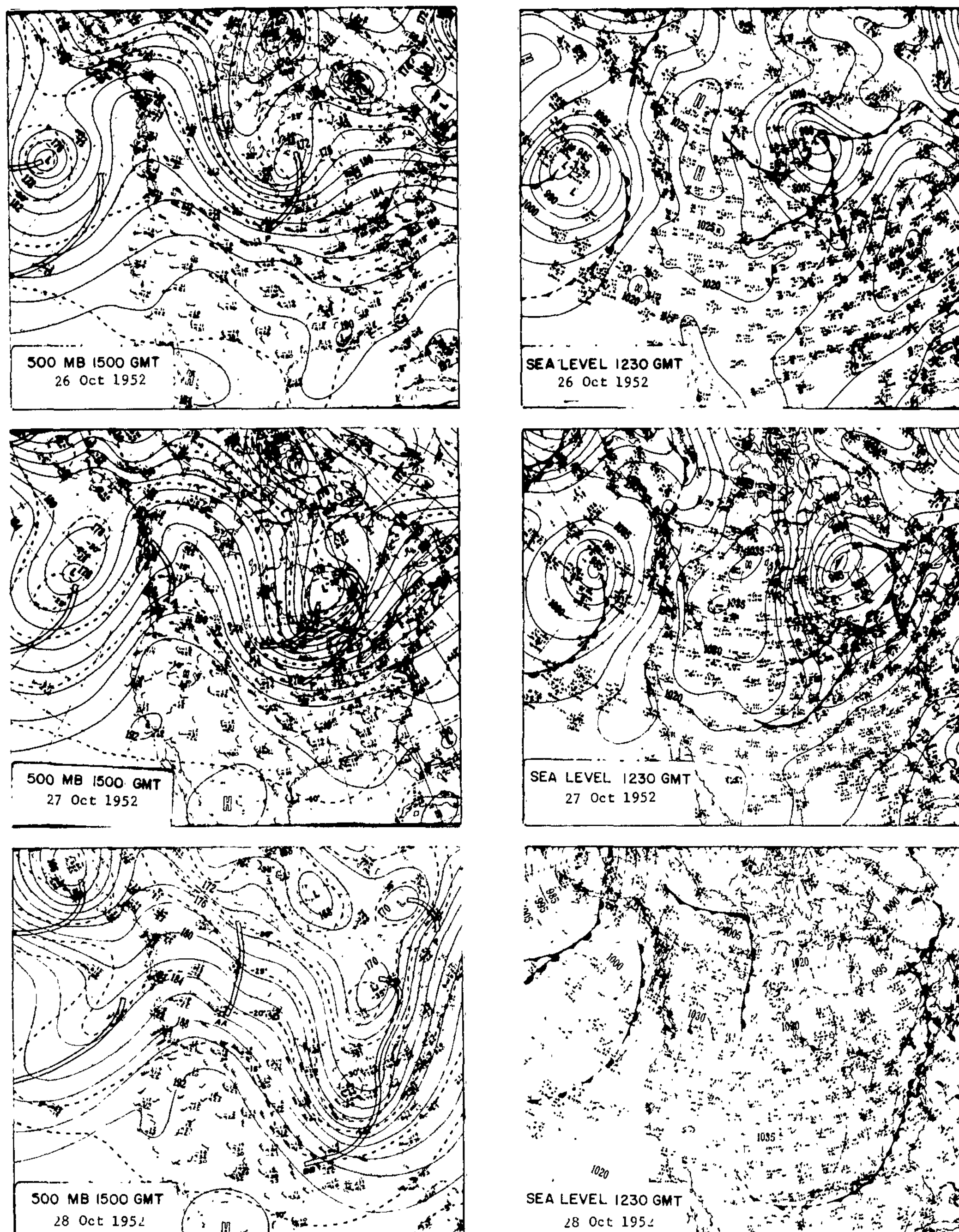


Figure 49. --Surface and 500 mb charts, October 26-31, 1952. High fire danger occurred in the West Gulf States on October 27, 28, and 29.

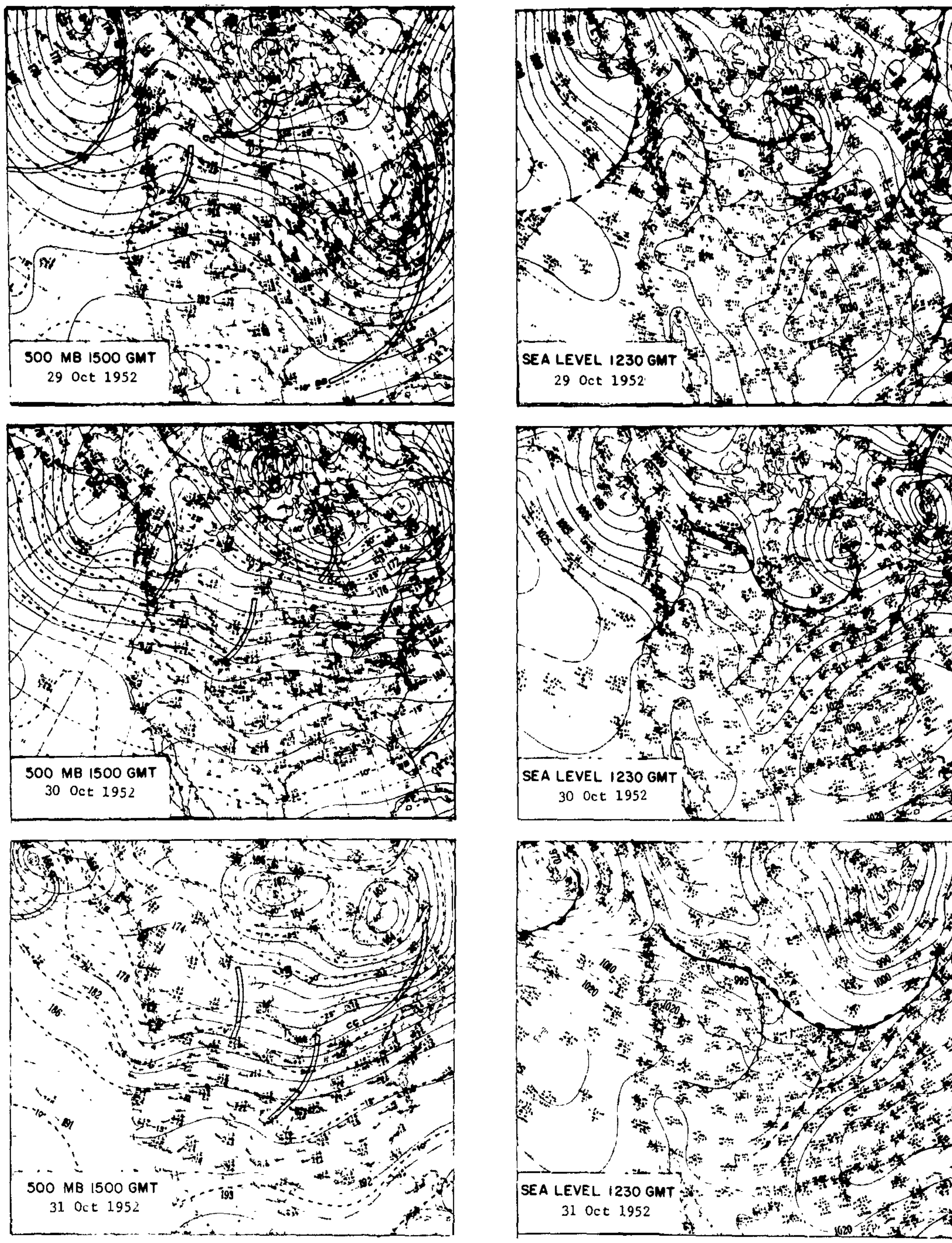


Figure 49. --Continued.

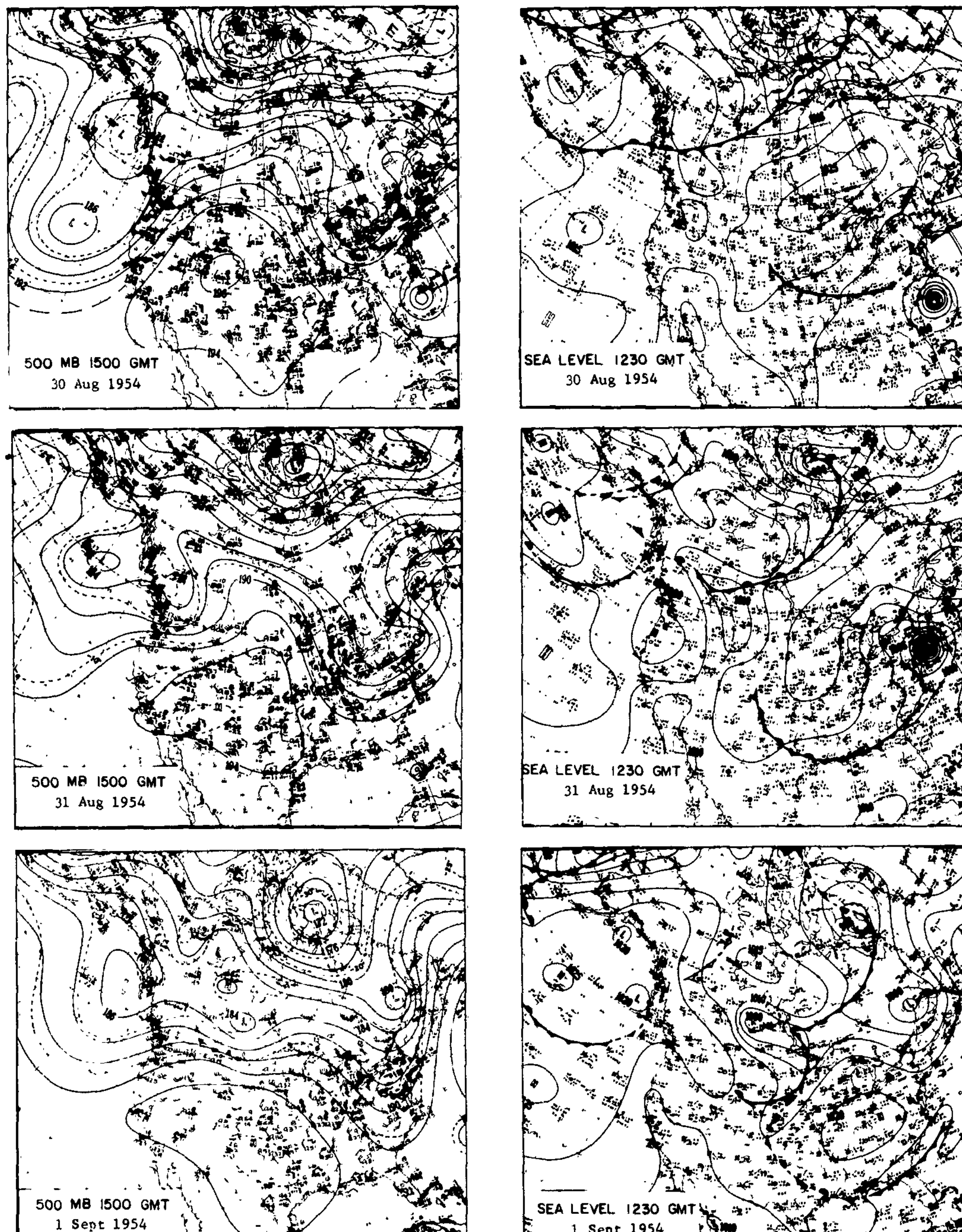


Figure 50. --Surface and 500 mb charts, August 30-September 4, 1954.

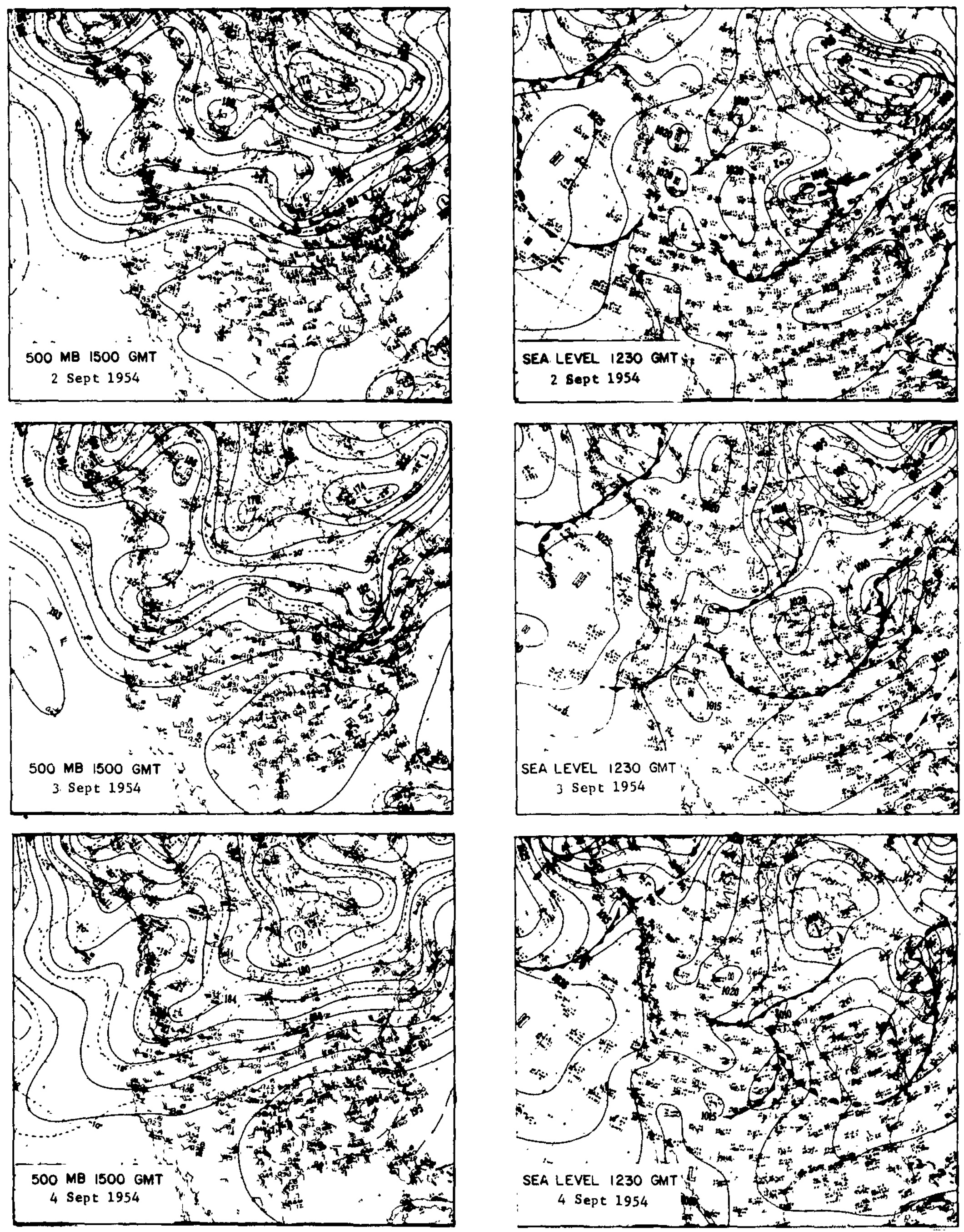


Figure 50. --Continued.

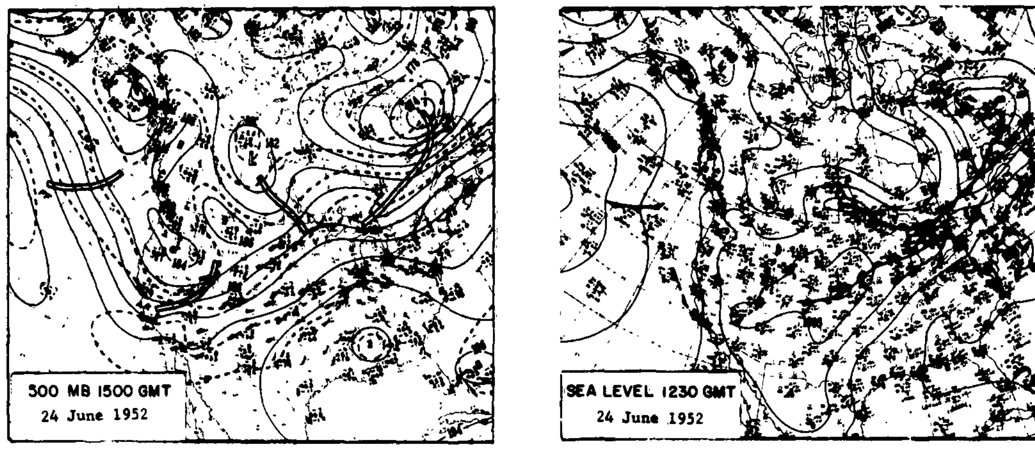
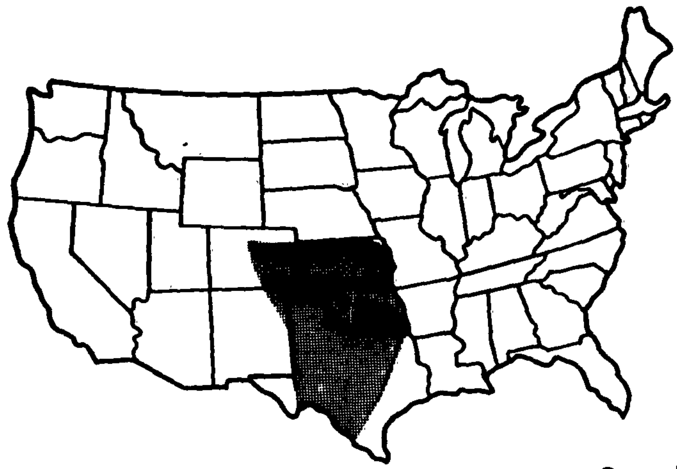


Figure 51. --Surface and 500 mb charts, June 24, 1952.



Southern Plains Region

The Southern Plains region includes Kansas, Oklahoma, eastern Colorado, and interior Texas except the extreme west. Stations used to represent this region are Dodge City, Kans., Oklahoma City, Okla., Pueblo, Colo., and Amarillo, Abilene, Waco, and San Antonio, Tex.

The climate of the region may be classified as dry or semi-arid. Near the western boundary of the region a high range of mountains, which begins in Mexico and extends northward through New Mexico and Colorado, effectively blocks moisture entering the region from the west or southwest. Air moving into the region across the mountains descends and warms adiabatically and brings high temperatures and low humidities to the Southern Plains. Even within the Southern Plains region, air flowing eastward or southeastward continues to descend--from elevations greater than 4,000 feet in the northwest to less than 1,000 feet in the southeast.

Conversely, air flowing northwestward, which has picked up moisture from the Gulf of Mexico, cools adiabatically. Relative humidities increase and fog, clouds, or even light precipitation are produced.

Average annual rainfall ranges from less than 12 inches at Pueblo to over 30 inches at Oklahoma City and 28 inches at San Antonio. The wettest months are usually in spring and early summer and the driest months are in winter. The average number of days per year with measurable precipitation is around 70 in the western portion of the region to around 80 in the eastern portion.

Because of the dryness and the strong winds characteristic of the region, the average level of fire danger is quite high. To focus attention only on the most critical periods, a fire load index value of 50 was selected as the level above which cases were selected for study.

this value was reached or exceeded an average of 14 percent of the days during the 10-year period. The percentage varied from a high of 31 in 1956 to a low of 4 percent in 1958 (table 19). High fire danger was much more frequent in the drought years of 1951-1956 than in the comparatively easy years from 1957 to 1960. Spring and early fall months had the most days of extreme fire danger. Almost half of the days are in the months of March through June and another quarter in September and October. The fewest days are in the winter months, but even then extreme fire danger can occur because of chinook winds that blow down the eastern slope of the Rockies during this season.

Data for individual stations show that the number of days of extreme fire danger decreases considerably from the northwestern part of the region (Pueblo, Dodge City, and Amarillo) to the southeastern part (Waco and San Antonio) (table 20). This trend is due in part to the influence of chinook winds in the lee of the Rockies as well as to the precipitation and moisture advection patterns.

Study of the surface and 500 mb charts for the days of extreme fire danger revealed five synoptic weather types. They were the Pacific High, Northwest Canadian High, Hudson Bay High, Bermuda High, and the chinook types. These types resulted in 516 days of extreme fire danger (table 21). Four of the five types (all except the chinook) were the same as those that affected the West Gulf States and are described for that region. It is important, however, to distinguish differences in the occurrence of these four types and the way they affect the two regions.

The Pacific High Type

The Pacific High, which occurred more frequently than any other type, accounted for 35 percent of the days with extreme danger. It was most frequent in late winter and spring months and in early fall. The life history of the type is the same for the Southern Plains as it is for the West Gulf region. But because of the relative location of these regions the Pacific High affects the Southern Plains first, and its effect is more severe there. As the High moves on to the east, the Southern Plains frequently remain dry while Gulf moisture is advected into the West Gulf region. In the Southern Plains there is frequently little or no break between types. The extreme fire danger is found in either the post-frontal or pre-frontal areas although some preference was shown for the post-frontal area (table 22).

The Northwest Canadian High Type

The Northwest Canadian High accounted for 13 percent of the days of extreme danger. Again the pattern and its effects are similar to those described for the West Gulf region, except that the fire danger is more severe in the Southern Plains, tends to last longer, and frequently shows little or no break between types.

Table 19.--Number of days with fire load index 50 or above, Southern Plains region, 1951-60

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	Annual percen
1951	9	6	10	8	6	0	1	3	1	4	0	4	52	14
1952	1	4	7	4	4	10	2	6	7	7	2	0	54	15
1953	2	4	8	7	9	14	4	2	3	4	1	0	58	16
1954	1	10	7	7	0	9	8	6	8	2	0	3	61	17
1955	0	5	14	18	7	4	5	0	6	6	9	5	79	22
1956	4	4	13	11	13	14	6	12	19	9	1	7	113	31
1957	6	3	2	3	0	0	2	0	1	0	0	1	18	5
1958	0	0	0	2	0	3	1	0	1	4	1	1	13	4
1959	0	2	8	5	4	1	2	1	4	1	0	0	28	8
1960	0	1	1	1	4	3	3	4	6	0	0	0	23	6
Total	23	39	70	66	47	58	34	34	56	37	14	21	499	--

Table 20.--Number of days with fire load indexes 37 and above, by stations, Southern Plains region, 1951-60

Year	Pueblo			Dodge City			Amarillo			Abilene		
	Fire load index equal to or greater than--											
	37	50	75	37	50	75	37	50	75	37	50	75
1951	30	14	10	5	2	1	36	11	3	60	28	16
1952	20	11	2	43	18	4	31	13	4	55	25	9
1953	28	16	8	35	23	6	45	25	13	16	4	1
1954	30	13	7	38	24	5	63	29	11	39	14	6
1955	40	15	6	46	24	6	71	47	29	28	16	4
1956	65	37	9	74	49	18	82	52	27	53	21	8
1957	23	11	0	13	3	0	19	7	0	6	1	0
1958	20	8	4	10	3	0	9	3	1	5	2	0
1959	15	8	1	20	7	2	26	13	6	12	6	1
1960	18	6	1	16	10	2	9	3	2	9	3	0
Total	289	139	48	300	163	44	391	203	96	283	120	45

Year	Oklahoma City			Waco			San Antonio		
	37	50	75	37	50	75	37	50	75
1951	7	6	1	3	1	0	3	2	0
1952	8	1	0	2	0	0	3	1	1
1953	9	3	0	1	0	0	5	2	1
1954	0	0	0	3	2	1	15	5	3
1955	13	4	3	2	0	0	7	3	0
1956	39	17	4	29	10	2	11	5	1
1957	0	0	0	1	0	0	3	1	0
1958	1	0	0	0	0	0	1	1	0
1959	1	0	0	1	1	1	0	0	0
1960	1	1	1	4	2	0	1	1	0
Total	79	32	9	46	16	4	49	21	6

Table 21.--Number of cases and number of days with fire load index 50 and above by months and by type, Southern Plains region, 1951-60

Month	Pacific High	Northwest Canadian High	Hudson Bay High	Bermuda High	Chinook
January					
Cases	10	3	0	0	5
Days	14	4	0	0	5
February					
Cases	15	4	0	0	12
Days	18	5	0	0	18
March					
Cases	20	4	1	1	26
Days	26	6	1	1	41
April					
Cases	22	6	1	5	20
Days	32	6	1	6	24
May					
Cases	14	4	1	4	11
Days	23	4	1	6	17
June					
Cases	10	1	1	14	11
Days	12	1	1	28	20
July					
Cases	7	1	0	5	3
Days	8	1	0	21	3
August					
Cases	4	2	0	14	1
Days	4	3	0	24	1
September					
Cases	9	12	1	9	9
Days	12	22	1	14	9
October					
Cases	12	7	1	0	7
Days	18	7	1	0	9
November					
Cases	3	2	0	0	5
Days	3	6	0	0	8
December					
Cases	6	2	0	1	6
Days	10	2	0	2	6
Total					
Cases	132	48	6	53	116
Days	180	67	6	102	161
Percent of days	35	13	1	20	31

Table 22.--Number of days with fire load index 50 and above, by synoptic type and area, Southern Plains region

Area	Pacific High	Northwest Canadian High	Hudson Bay High	Bermuda High	Total
Post-frontal	121	29	5	5	160
Southern quadrant	6	1	0	0	7
Northern quadrant	6	2	0	0	8
Pre-frontal	100	51	5	127	283
Total	233	83	10	132	458

The Northwest Canadian High type is most frequent in spring and fall. The extreme fire danger is nearly always in the post-frontal or pre-frontal areas but the latter is more common.

The Hudson Bay High Type

The Hudson Bay High type accounted for only 1 percent of the days of extreme fire danger. In order for a high pressure area to travel from the Hudson Bay region to the Southern Plains, the flow pattern aloft must be extremely meridional. This type of pattern seldom occurs. Each of the cases during the 10-year period was only 1 day long. The Southern Plains region usually is affected by only the edge of this type and receives a glancing blow.

The Bermuda High Type

The Bermuda High type is almost exclusively a summertime phenomenon. It accounted for 20 percent of the critical fire-weather days. Because of the location of the Southern Plains region with respect to the Bermuda High extension, the area of extreme fire danger was nearly always the pre-frontal area on the western or northwestern side of the High. The fire danger reached its peak in the strong gradient zone ahead of advancing fronts and particularly in the warm sector area of frontal waves passing to the north.

Periods of high fire danger associated with the Bermuda High type can be quite long in the Southern Plains. Even when the Bermuda High retreats eastward far enough so that moist air can be advected into the West Gulf region, very frequently the trajectory of air reaching the Southern Plains is from Mexico and on into Texas and northward. The West Gulf region may get temporary relief and sometimes thundershowers while the Southern Plains remain dry.

The Chinook Type

The foehn-type wind which crosses the Rocky Mountains from the west and flows down the east slopes is known locally as the Chinook. It affects a band east of the Rockies from the Canadian border to Texas and extends for a short distance out into the western Plains. The downward flowing air is heated by compression and its relative humidity drops to low values, frequently lower than 5 percent.

The upper-air pattern favorable for a chinook is one in which rather strong westerly winds blow at nearly right angles to the Rocky Mountain range. Preferably there should be a ridge over or to the west of the Rockies, for this pattern favors subsidence from high levels in the atmosphere down to near the mountain tops.

At the surface a Pacific or Northwest Canadian High is usually situated over the Plains and another High over the Great Basin. A front lies in the trough between these two Highs. As a low pressure center north of the region moves eastward, the front also moves eastward away from the Rocky Mountains. The critical area in which chinook winds blow is between the front and the Rocky Mountain Range. Usually this area is within the warm sector of the frontal system to the north. Within the warm sector in the area where the air is flowing down the east slope of the Rockies, the winds are strong, temperatures are high, and humidities acutely low. This combination of factors produces critical fire weather.

During the 10-year period of study, chinook winds accounted for 31 percent of the extreme fire danger days. Most of these occurred in late winter and spring months.

The period November 11-15, 1956 is an excellent example of a chinook situation (fig. 52). The chinook winds began first in the northwestern Plains and then progressed southward along the eastern slopes of the Rockies. November 11 a strong belt of westerlies was crossing the northern Rockies and a ridge was approaching from the west. At the surface, a High was located in the Great Basin and a Pacific High was moving eastward through British Columbia. By early morning November 12 the Pacific High had moved to the central Plains and a vigorous Low was entering Canada from the Gulf of Alaska. During the day chinook winds set in behind the warm front in the northwestern Plains and the fire danger became high in eastern Wyoming and parts of Montana.

The belt of westerlies moved farther south as the short-wave trough associated with the surface Low moved inland November 13. Within the warm sector of the Low, chinook winds blew down the slope of the central Rockies. The fire load index at Casper reached 56, at Pueblo 99, and at Amarillo 45. Fire dangers lowered north of the cold front.

By November 14 a secondary Low had developed and crossed the central Rockies. In its warm sector to the south the down-flowing chinook wind brought a fire load index of 60 to Roswell, 40 to Amarillo, and 45 to Abilene. North of the cold front the fire danger was very low. November 15 the short-wave trough aloft and the surface cold front passed on eastward. Cold Pacific air covered the entire Plains regions and fire danger was generally low throughout the chinook belt.

In predicting the chinook wind, the critical conditions to look for are the strong westerlies crossing the Rockies aloft and the warm sector of a surface Low moving across the Rockies and into the Plains.

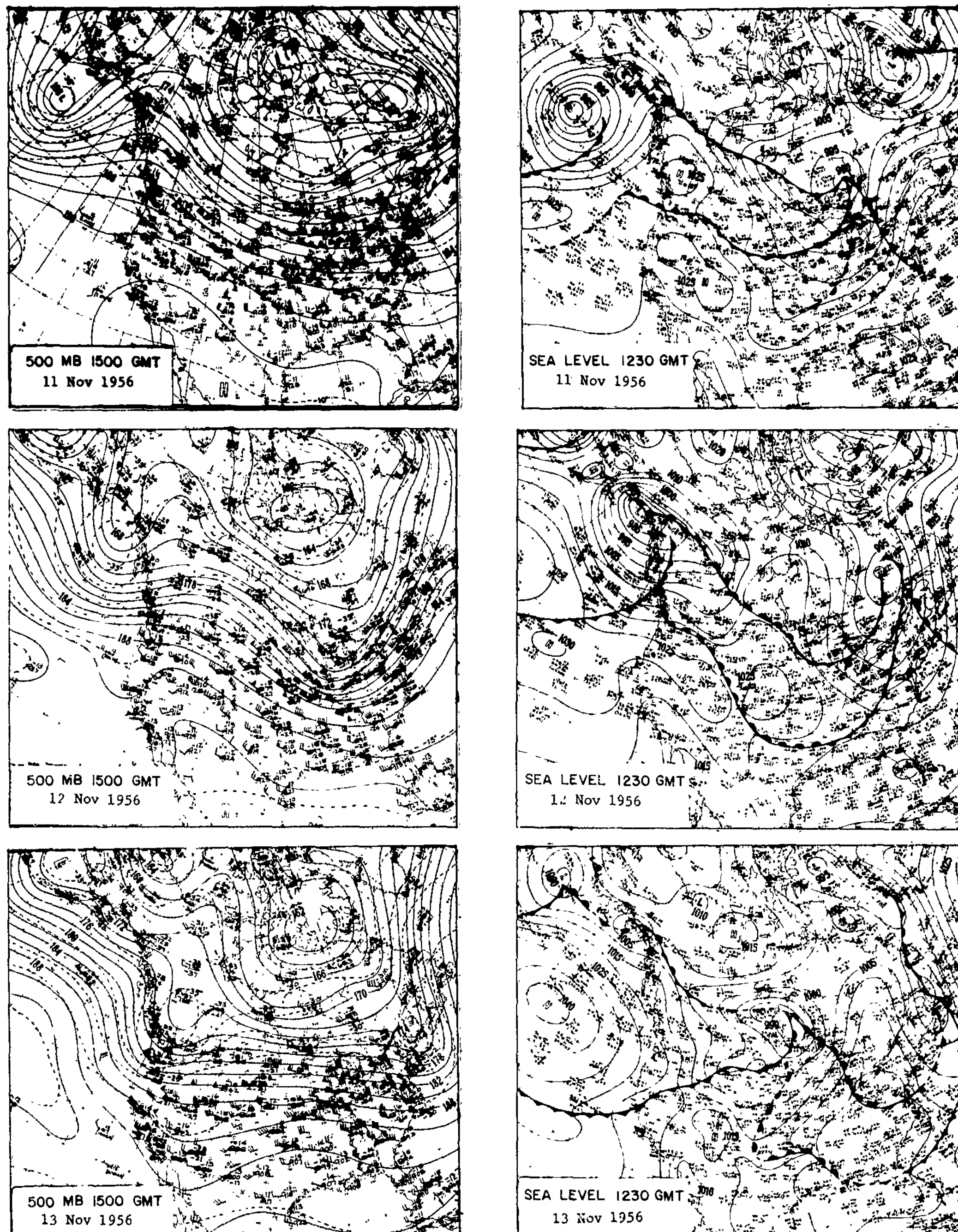


Figure 52. --Surface and 500 mb charts, November 11-15, 1956.

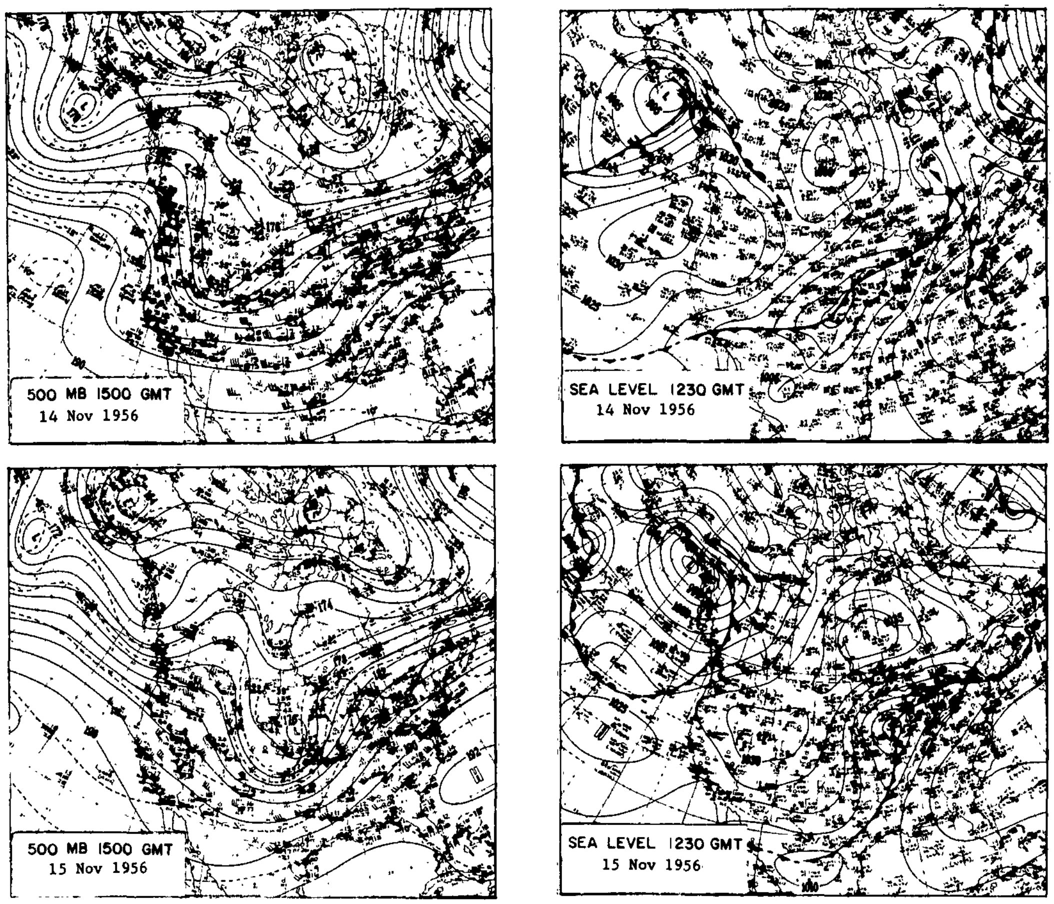
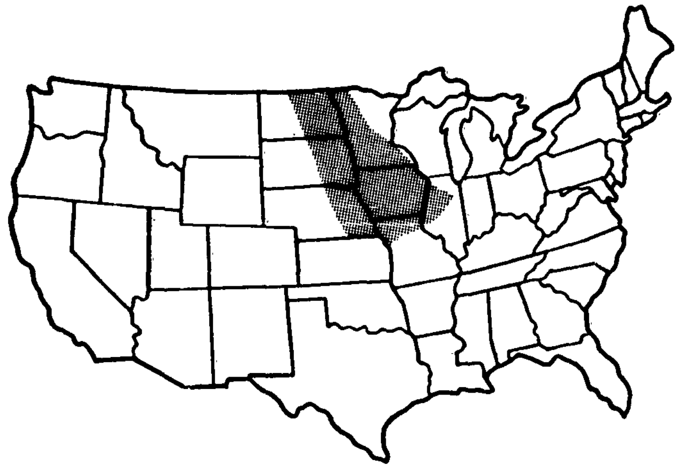


Figure 52. --Continued.



Northeast Plains Region

The Northeast Plains region includes the eastern portions of the Dakotas and Nebraska, the southwestern half of Minnesota, Iowa, and northwestern Illinois. The weather stations used to represent this area were Fargo, N. Dak., Sioux Falls, S. Dak., Minneapolis, Minn., Des Moines, Iowa, and Moline, Ill.

The Northeast Plains has a single fire season lasting from April through October. Rare cases of high fire danger occur in March and November. During the winter months, most of the region is snow-covered and fire danger is low. The months of maximum occurrence of high fire danger are May, September, and October. More than half of the cases occur in these three months.

A fire load index of 22 or greater is reached at stations in the region an average of slightly less than 5 percent of the days during April through October. A fire load index of 22, the same level used for the Northwest Plains, was used to indicate high fire danger days at all stations in the Northeast Plains region except Minneapolis (table 23). At Minneapolis, which is on the eastern edge of the Plains, the general level of fire danger is somewhat lower. There, a fire load index of 17 was used, as in the adjoining Lake States region. The value 17 or greater was reached on about 4 percent of the April-October days at Minneapolis. (More detailed information on the distribution of fire load indexes is found in Appendix A.)

Table 23.-- Number of days of fire load index above specified levels, by stations, Northeast Plains region, 1951-60

Year	Fargo			Sioux Falls			Des Moines			Moline			Minneapolis		
	Fire Load index equal to or greater than--														
	22:	37:	50:	22:	37:	50:	22:	37:	50:	22:	37:	50:	17:	22:	37:
1951	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1952	26	9	3	21	6	1	5	1	0	12	2	0	8	4	1
1953	11	3	1	13	4	1	20	6	3	13	1	1	11	5	1
1954	7	0	0	5	1	0	10	2	0	4	0	0	3	3	0
1955	19	5	1	35	10	4	22	3	1	8	1	1	15	7	0
1956	12	7	2	37	11	3	25	5	3	17	5	1	14	8	1
1957	2	0	0	4	0	0	3	0	0	2	0	0	4	2	1
1958	9	2	0	14	3	1	4	0	0	2	0	0	7	3	0
1959	18	3	0	17	2	0	2	0	0	0	0	0	12	8	1
1960	10	3	1	6	0	0	1	0	0	0	0	0	3	1	0
Total	115	32	8	152	37	10	92	17	7	58	9	3	78	41	5

According to the level of fire load index selected, there were 182 cases of high fire danger and a total of 349 days (tables 24 and 25). For this region the cases were grouped into four synoptic types:

1. Pacific High
2. Northwest Canadian High
3. Hudson Bay High
4. Bermuda High

In most cases (56 percent) the period of high fire danger lasted only one day (table 26). The average, however, was slightly less than 2 days. About 7 percent of the cases lasted 5 days or longer and a few of these lasted 9 days. Occasionally, particularly in spring and fall seasons, one weather type will follow another without any break in high fire danger and produce periods of 15 days or more.

Table 24.--Number of cases and number of days with fire load index 22 or above[1/], by synoptic type, Northeast Plains region, 1951-60

Year	Pacific High	Northwest Canadian High	Hudson Bay High	Bermuda High	Total
1951					
Cases	2	0	0	0	2
Days	2	0	0	0	2
1952					
Cases	17	5	5	0	27
Days	29	15	8	0	52
1953					
Cases	18	0	3	1	22
Days	35	0	9	2	46
1954					
Cases	13	1	4	2	20
Days	19	1	4	2	26
1955					
Cases	16	3	4	3	26
Days	47	6	8	9	70
1956					
Cases	16	6	3	5	30
Days	35	11	8	7	61
1957					
Cases	3	1	1	2	7
Days	6	1	4	3	14
1958					
Cases	13	3	4	0	20
Days	21	4	4	0	29
1959					
Cases	13	1	2	1	17
Days	28	3	2	1	34
1960					
Cases	6	2	2	1	11
Days	7	2	5	1	15
Total					
Cases	117	22	28	15	182
Days	229	43	52	25	349
Percent of days	66	12	15	7	100

1/ except 17 or above at Minneapolis.

Table 25.--Number of cases and number of days with fire load index 22 or above 1/ by synoptic type and month, Northeast Plains region, 1951-60

Month	Pacific High	Northwest Canadian High	Hudson Bay High	Bermuda High	Total
Jan.					
Cases	0	0	0	0	0
Days	0	0	0	0	0
Feb.					
Cases	0	0	0	0	0
Days	0	0	0	0	0
Mar.					
Cases	1	0	0	0	1
Days	1	0	0	0	1
Apr.					
Cases	20	4	1	1	26
Days	43	7	1	1	52
May					
Cases	15	3	13	1	32
Days	36	4	25	1	66
June					
Cases	9	0	2	4	15
Days	20	0	3	6	29
July					
Cases	14	2	3	3	22
Days	21	2	3	8	34
Aug.					
Cases	9	0	1	3	13
Days	28	0	1	6	35
Sept.					
Cases	20	7	3	3	33
Days	35	17	5	3	60
Oct.					
Cases	23	6	5	0	34
Days	37	13	14	0	64
Nov.					
Cases	6	0	0	0	6
Days	8	0	0	0	8
Dec.					
Cases	0	0	0	0	0
Days	0	0	0	0	0
Total					
Cases	117	22	28	15	182
Days	229	43	52	25	349

1/ except 17 or above at Minneapolis.

Table 26.--Duration of cases with fire load index 22 and above[1/] by synoptic type and season, Northeast Plains region, 1951-60

Duration in days	Pacific High	Northwest Canadian High	Hudson Bay High	Bermuda High	Total
		SPRING			
1	13	4	7	2	26
2	11	2	4	0	17
3	5	1	1	0	7
4	5	0	2	0	7
5 or more	2	0	0	0	2
		SUMMER			
1	19	2	5	4	30
2	5	0	1	4	10
3	3	0	0	1	4
4	0	0	0	0	0
5 or more	5	0	0	1	6
		FALL			
1	32	7	4	3	46
2	9	1	1	0	11
3	6	2	2	0	10
4	0	1	0	0	1
5 or more	2	2	1	0	5

1/ Except 17 and above at Minneapolis.

The Pacific High Type

The Pacific High type was the most frequent type in the Northeast Plains. It accounted for 117 cases and 229 days (66 percent) of high fire danger (table 27). Most of the cases occurred in the late spring and early fall months. Most cases lasted only one day although the average was two days and they ranged as high as 9 days. The highest fire load index, 80, was found with this type, and 40 cases had 37 or higher.

Table 27.--Number of cases and days with fire load index 22 and above[1] for the Pacific High type, Northeast Plains region, 1951-60

Season and area	No. of cases	No. of days	Longest duration	Highest FLI
Spring:				
Post-frontal	9	14	3	54
Pre-frontal or warm sector	11	23	4	66
North or south quadrant	3	4	2	40
Combination[2]	13	39	5	62
Total	36	80	--	--
Summer:				
Post-frontal	11	13	3	45
Pre-frontal or warm sector	12	15	2	40
North or south quadrant	0	0	0	0
Combination	9	41	9	54
Total	32	69	--	--
Fall:				
Post-frontal	15	19	3	43
Pre-frontal or warm sector	22	31	3	69
North or south quadrant	3	3	1	34
Combination	9	27	7	80
Total	49	80	--	--
Total:				
Post-frontal	35	46	3	54
Pre-frontal or warm sector	45	69	4	69
North or south quadrant	6	7	2	34
Combination	31	107	9	80
Total	117	229	--	--

1/Except 17 or above at Minneapolis.
2/"Combination" refers to a case of high fire danger involving two or more areas.

The Pacific High type originates as a break-off from the Pacific high pressure cell in the Pacific Northwest or southwest Canada. It then moves eastward or southeastward to the northern Plains. The track that it takes depends upon the flow pattern aloft. In most cases the flow is zonal or meridional with the ridge to the west of the region. A number of block patterns and short-wave train patterns were also found. In the latter cases the surface High associated with the short-wave usually travels an easterly course. When there is a block over the Pacific, the flow over the continent is usually zonal. If the block is along the West Coast, the ridge portion of the block acts like a meridional ridge in steering Pacific Highs.

The Pacific High moves into the northern Plains following a Pacific cold front. The air mass loses most of its moisture in crossing the Rockies and may gain some heat from the condensation process. It arrives in the region as a comparatively dry and mild air mass.

High fire danger is usually in either the post-frontal or pre-frontal areas and occasionally in the north or south quadrants. High fire danger in the post-frontal area usually occurs when the High moves through or slightly north of the region. This type of trajectory is commonly associated with a zonal pattern, or occasionally a short-wave train pattern, aloft. Several other conditions are also necessary: (1) the cold front passage must be dry or with nothing more than scattered light showers, (2) the temperatures in the forward portion of the High should be moderate although they need not be high, and (3) the wind speed must be relatively strong, of the order of 20 mph or more. An added feature which indicates sinking air and drying is the divergence of the sea level isobars in the post-frontal area. Post-frontal high fire danger usually lasts only one day and decreases as winds diminish toward the center of the High. At times a wave will develop on the Pacific front southwest of the region and move northeastward. This usually produces precipitation and may prevent post-frontal high fire danger, or end it if it has developed.

High fire danger is found most frequently in the pre-frontal or warm sector area on the western or northern side of the High after the center has reached a position over the Southern Plains or middle Mississippi Valley. By this time a low pressure center is usually moving eastward near the Canadian border. The highest fire dangers are found in the pre-frontal or, particularly, the warm sector area of this system where temperatures are rising and winds are increasing. The highest fire load index (80) was recorded in this area. Pre-frontal fire danger usually ends with the passage of the front, particularly if precipitation accompanies the cold front. Otherwise, lower temperatures, higher humidities, and decreased winds lower the danger. If dry fronts pass along the north side of the High, the fire danger may continue high behind the front and decrease only when the winds drop off.

The charts for November 1-6, 1952 (fig. 53) illustrate the Pacific High type and how it affects this region. The upper-air flow, which had been decidely zonal, began to develop a ridge in western Canada November 1 and temporarily took on the characteristics of a block November 2. A portion of the Pacific high pressure cell entered the Pacific Northwest behind a double low pressure system and moved toward the Northern Plains. Fire danger became high in the post-frontal area on November 1 and decreased slightly as winds diminished November 2. An important feature in this case was the large surface High that covered the Southeast and the Gulf States and kept moisture out of the Northern Plains. Another low pressure system moved into western Canada November 2 and moved eastward. Its frontal system extended southward;part of the Northeast Plains got into the warm sector November 3, and Sioux Falls recorded a fire load index of 27.

The flow aloft became more northwesterly over central United States as a block redeveloped near the West Coast November 4. The surface High was carried far to the south while another frontal system approached the region. Again the source of moisture from the Gulf of Mexico was cut off. The next front passed through the Northeast Plains dry, and was followed by a second Pacific High. In the post-frontal area where the pressure gradient was strong, fire load indexes reached 37 at Sioux Falls, 24 at Des Moines, and 20 at Moline on November 5. The fire danger decreased November 6 as the center of the High approached the region and winds decreased.

The Northwest Canadian High Type

The Northwest Canadian High type accounted for 22 cases and 43 of the days (12 percent) of high fire danger. These cases were mainly in April, May, September, and October (table 25). Most lasted only 1 day, the average was 2 days, and the longest duration was 6 days. The highest fire load index was 73; 9 cases had 37 or higher.

With this type a high pressure area develops in northwest Canada or eastern Alaska and moves southeastward under the northwesterly flow of a meridional ridge or the ridge portion of a block. The ridge is near or off the West Coast and may extend into Alaska.

The high fire danger usually is found in either the post-frontal or pre-frontal area of the High (table 28). Post-frontal periods are usually short. The conditions necessary for high fire danger with the Pacific High apply to this type also. The pre-frontal or warm sector area is usually more critical. The highest fire load index, 73, encountered with the Northwest Canadian type was found in this area.

An example of this synoptic type is shown by the charts for October 26-30, 1952 (fig. 54). On October 26, a High in northwest Canada was moving southeastward behind a vigorous Low and its associated fronts. The flow pattern aloft was decidedly meridional, with the ridge along the West Coast. Gulf moisture was cut-off by a High

Table 28.--Number of cases and days with fire load index 22 and above[1] for Northwest Canadian High type by season and area, Northeast Plains Region, 1951-60

Season and area	No. of cases	No. of days	Longest duration	Highest FLI
Spring:				
Post-frontal	4	5	2	29
Pre-frontal or warm sector	1	1	1	27
North or south quadrant	1	2	2	34
Combination	1	3	3	40
Total	7	11	--	--
Summer:				
Post-frontal	0	0	0	0
Pre-frontal or warm sector	2	2	1	31
North or south quadrant	0	0	0	0
Combination	0	0	0	0
Total	2	2	--	--
Fall:				
Post-frontal	4	5	2	43
Pre-frontal or warm sector	6	13	6	73
North or south quadrant	0	0	0	0
Combination	3	12	5	73
Total	13	30	--	--
Total:				
Post-frontal	8	10	2	43
Pre-frontal or warm sector	9	16	6	73
North or south quadrant	1	2	2	34
Combination	4	15	5	73
Total	22	43	--	--

1/Except 17 and above at Minneapolis

centered in the East. High fire danger occurred in the Northeast Plains in the post-frontal area October 27, with Moline reaching 27. The fire danger diminished October 28 as the High passed southeastward through the Plains.

October 29, with the High centered over Arkansas, the Northeast Plains came under the influence of the warm sector of a Low passing eastward to the north. The fire load index at Sioux Falls rose to 40, at Moline to 22, and at Des Moines to 20. Another surface trough approached the region from the west October 30, and in the strong gradient area on the fore side of the trough the fire load index at Des Moines reached 40, at Moline 45. The flow aloft by this time had changed to zonal and a Pacific High approached the region behind the surface trough. High fire danger continued in the Northeast Plains October 31 as the Pacific High moved in.

The Hudson Bay High Type

The Hudson Bay High type occasionally affects the Northeast Plains although usually it affects regions farther to the east. During the 10-year period of study, it accounted for 28 of the high fire danger cases, and 52 (15 percent) of the days. The month of greatest frequency was May with 13 of the cases; October was second with 5 (table 25). No cases were found during the months November through March. The May maximum is probably due to the fact that Hudson Bay remains frozen, and therefore colder, longer than the land areas of Canada. It is, therefore, a good source region for continental polar air well into May.

In order for a High from the Hudson Bay region to affect the Northeast Plains, the steering current aloft must be strongly meridional and the ridge over western Canada. At times the High moves south-southwestward toward the Plains under a north-northeast flow aloft. Such a flow aloft results when an omega-type ridge forms over western Canada and a closed Low aloft near the southern shore of Hudson Bay.

As the High moves southward, the air mass is warmed by solar radiation, by passing over warmer land, and by subsidence. It reaches the Northeast Plains as a relatively dry air mass, particularly in the spring months.

Occasional high fire danger is found in the post-frontal area on the fore side of the High, but the highest danger is found on the western side in the pre-frontal or warm sector area. Usually the High changes direction as it reaches the central portion of the country and moves eastward to the East Coast as the flow pattern aloft becomes more zonal. The Northeast Plains is then on the western or northwestern side of the High, where the winds are southerly and the air is warmed considerably. As the gradient increases ahead of the next approaching front, the fire danger becomes high.

The average duration of the period of high fire danger is 2 days but some cases have lasted 7 days (table 29). The highest fire load index was 66 and there were six cases with 37 or higher.

The Hudson Bay High type may be followed by either Pacific or Northwest Canadian Highs without a definite break in the fire danger. If a break does follow this type, it is brought about by moisture advected into the region in the southerly current, by precipitation with the frontal passage, or by a cold air mass following the frontal passage.

May 22-26, 1956 is an example of this type (fig. 55). May 22 the High was just west of Hudson Bay and moving southward under the northerly current aloft on the east side of the meridional ridge in western Canada. It moved into the region May 23, but the gradient was very weak and high fire dangers were not reported. May 24, when the center of the High was in the Lake States, and May 25, when it had moved to the Atlantic Coast, the Northeast Plains was in the pre-frontal area on the west side of the High. Southerly winds brought higher temperatures and lower humidities to the region. The fire load index rose to 32 at Sioux Falls May 24 and to 40 at Moline May 25. The fire danger lowered at all stations May 26 as a Low center passed through the region.

The Bermuda High Type

The Bermuda High type affects the Northeast Plains only infrequently. Fifteen cases were recorded during the 10-year study period, and these accounted for 25 percent of the high fire danger days. It is a summertime phenomenon.

The flow pattern aloft with the Bermuda High type is usually zonal with the belt of westerlies far north near the Canadian border. A meridional ridge, or the ridge portion of a block, over mid-continent is also favorable for this type. Frequently there is a closed anti-cyclonic circulation over the southern portion of the country.

The surface pattern is characterized by a westward extension of the Bermuda High to Texas and sometimes to New Mexico. Dry, hot air from Mexico flows northward through the Plains and may reach the Northeast Plains region. Often the dry air will reach only the southern portion of the region while the part of the region north of an east-west cold front is under the influence of a cooler air mass. Peaks in the fire danger are reached when short-wave troughs with associated weak frontal systems at the surface pass eastward to the north of the region.

The high fire danger usually ends when a cold front passes through the region and ends the hot spell caused by the Bermuda High type.

Table 29.--Number of cases and days with fire load index 22 and above[1] for Hudson Bay High type, by season and area, Northeast Plains region, 1951-60

Season and area	No. of cases	No. of days	Longest duration	Highest FLI
Spring:				
Post-frontal	4	5	2	34
Pre-frontal or warm sector	4	8	4	40
North or south quadrant	2	2	1	25
Combination[2]	4	11	4	66
Total	14	26	--	--
Summer:				
Post-frontal	0	0	0	0
Pre-frontal or warm sector	5	6	2	34
North or south quadrant	1	1	1	23
Combination	0	0	0	0
Total	6	7	--	--
Fall:				
Post-frontal	1	1	1	24
Pre-frontal or warm sector	5	8	3	49
North or south quadrant	0	0	0	0
Combination	2	10	7	34
Total	8	19	--	--
Total:				
Post-frontal	5	6	2	34
Pre-frontal or warm sector	14	22	4	49
North or south quadrant	3	3	1	25
Combination	6	21	7	66
Total	28	52	--	--

1/Except 17 and above at Minneapolis.
2/"Combination" refers to a case of high fire danger involving two or more areas.

The period July 25-27, 1956 illustrates a case in which the Bermuda High affected the southern portion of the region (fig. 56). The flow aloft July 25 was zonal with the belt of westerlies far north. At the surface, the Bermuda High extended westward to New Mexico, but most of the Northeast Plains region was under the influence of a polar air mass. July 26 the southern portion of the region came into the warm sector of a system passing to the north. The fire load index at Des Moines jumped from 6 July 25 to 27 July 26, as the wind changed from N 7 to SW 16, the temperature rose from 86°F to 102°F, and the relative humidity dropped from 32 percent to 26 percent. Des Moines was the only station that reported high fire danger. At Moline the wind increased from N 10 to S 19 and the temperature increased from 85° to 91°F, but the air reaching this part of the region was more moist and the humidity rose from 45 to 51 percent.

July 27 the cold front moved through the entire Northeastern Plains region causing scattered precipitation. Temperatures lowered, relative humidities increased, winds decreased, and the fire danger period ended.

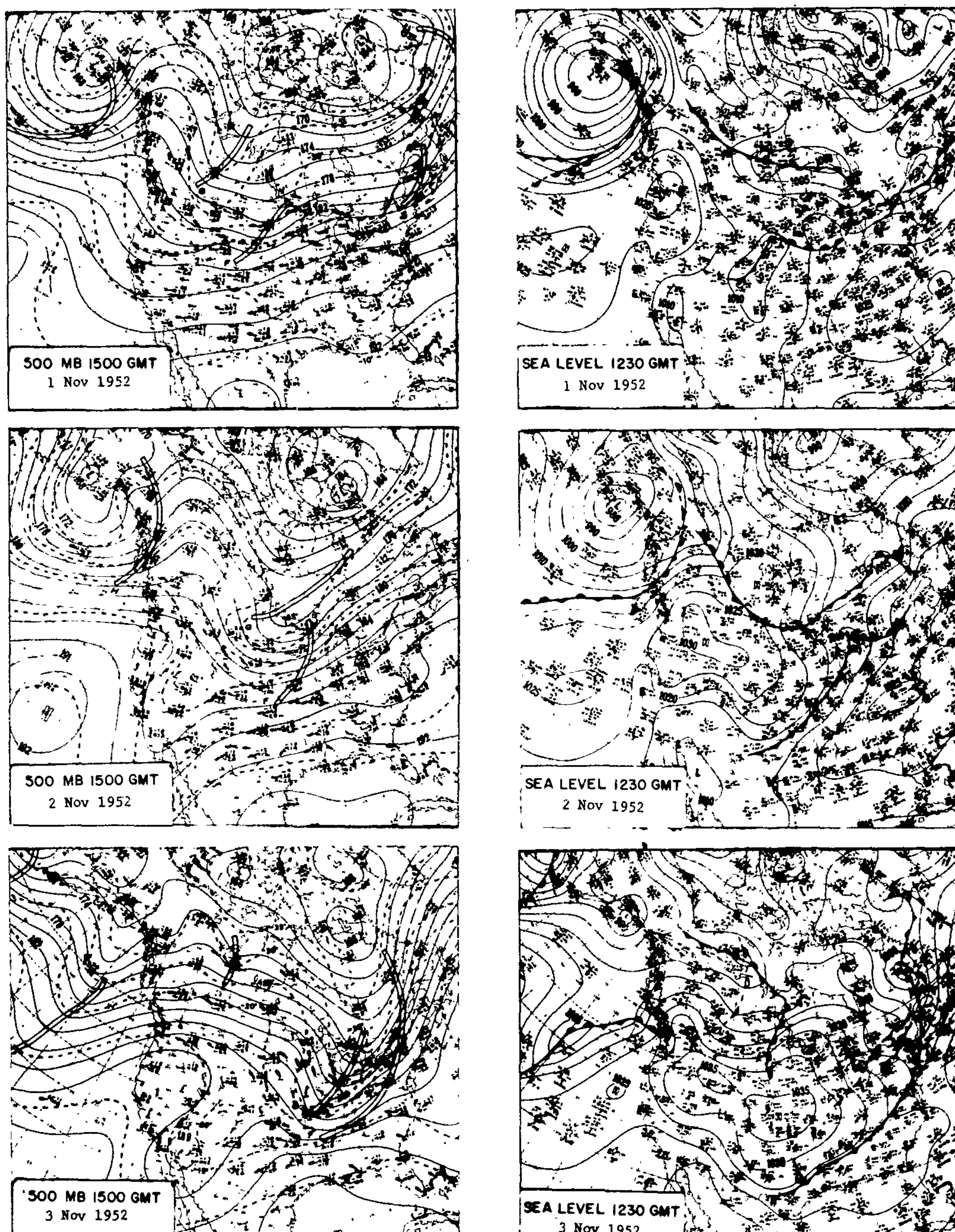


Figure 53. --Surface and 500 mb charts, November 1-6, 1952. High fire danger occurred in the post-frontal, north quadrant, and warm sector areas of the first Pacific High, and in the post-frontal area of the second Pacific High on November 6.

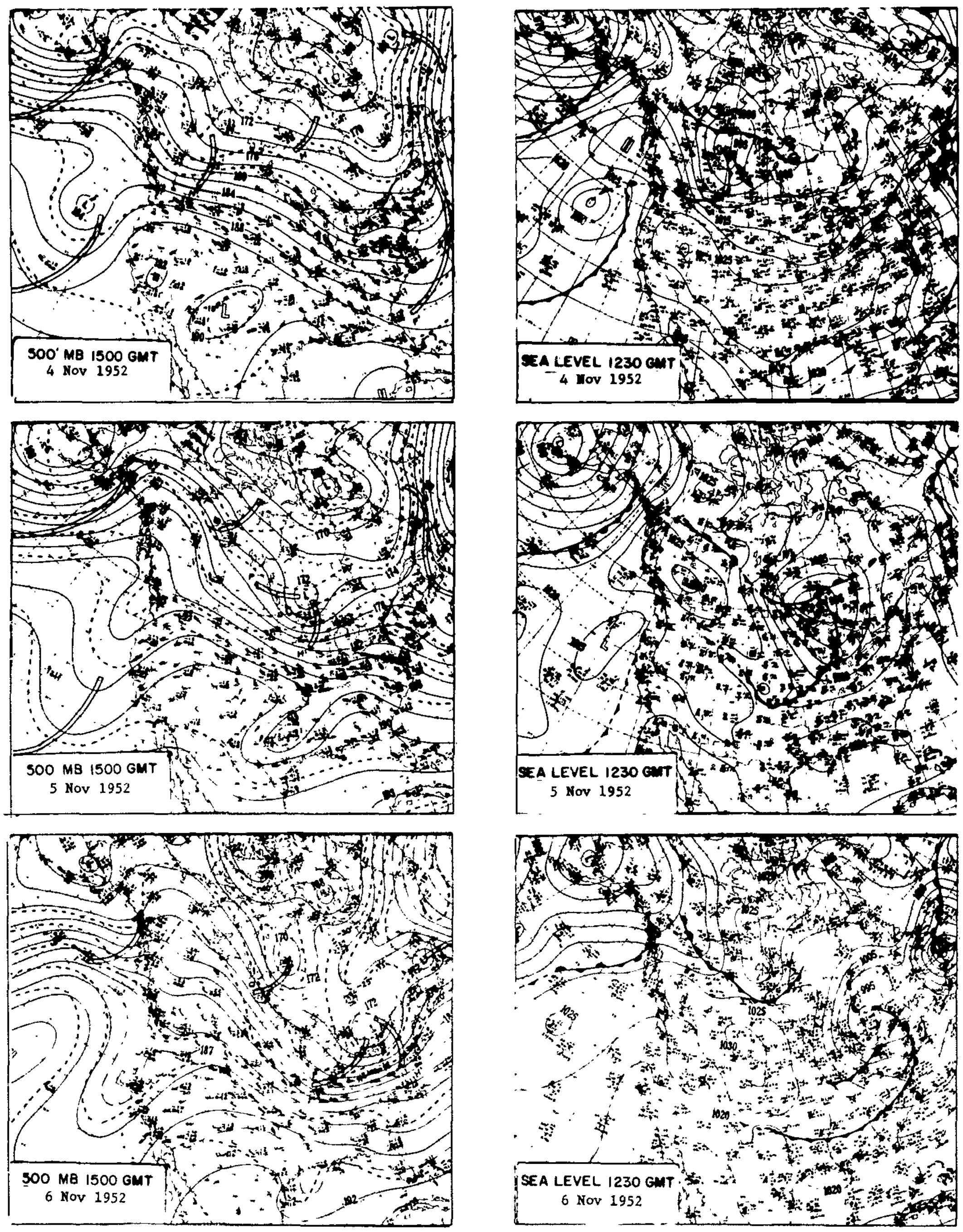


Figure 53. --Continued.

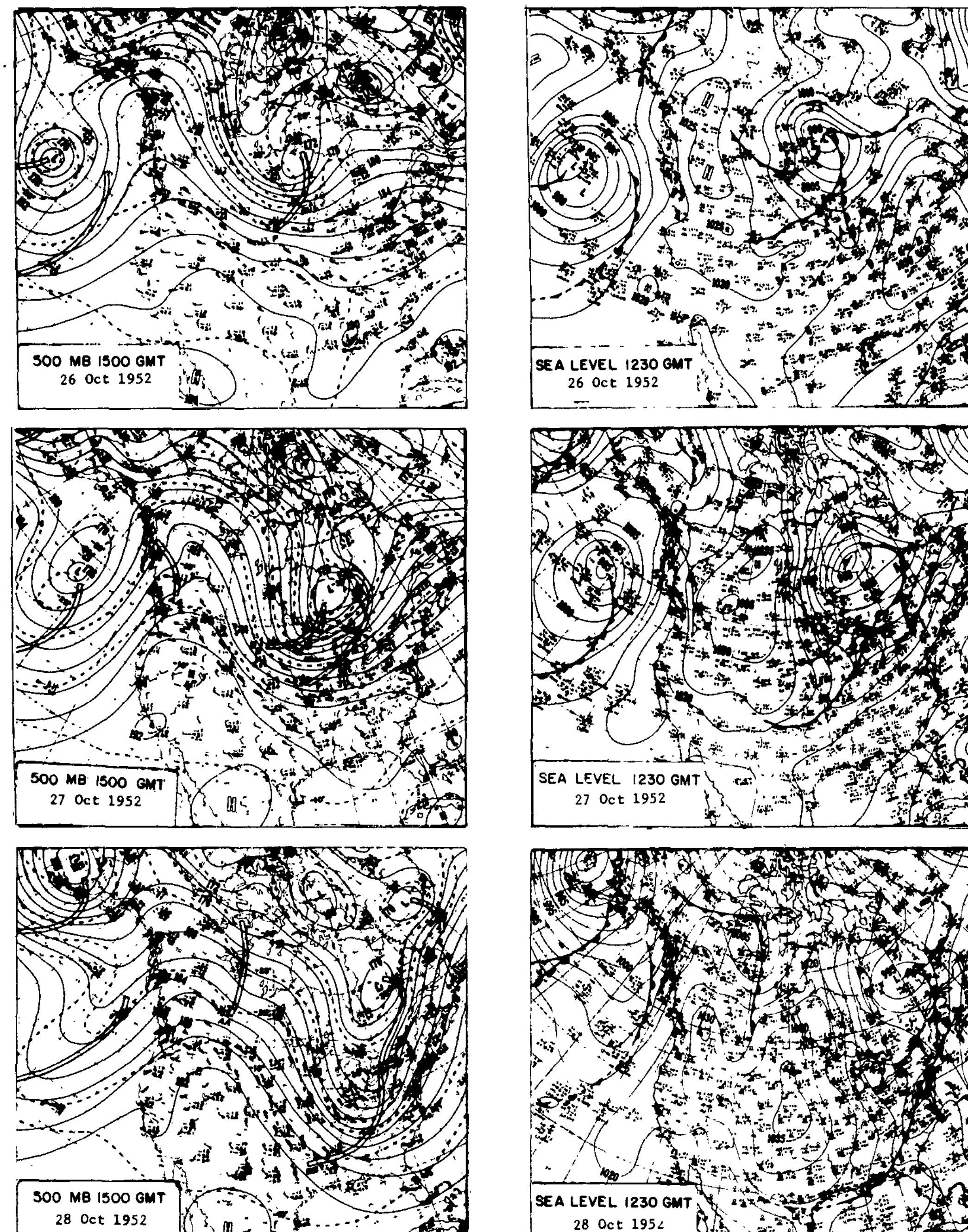


Figure 54. --Surface and 500 mb charts, October 26-30, 1952. High fire danger occurred in the post-frontal area on October 27 and in the warm sector and pre frontal areas October 29 and 30.

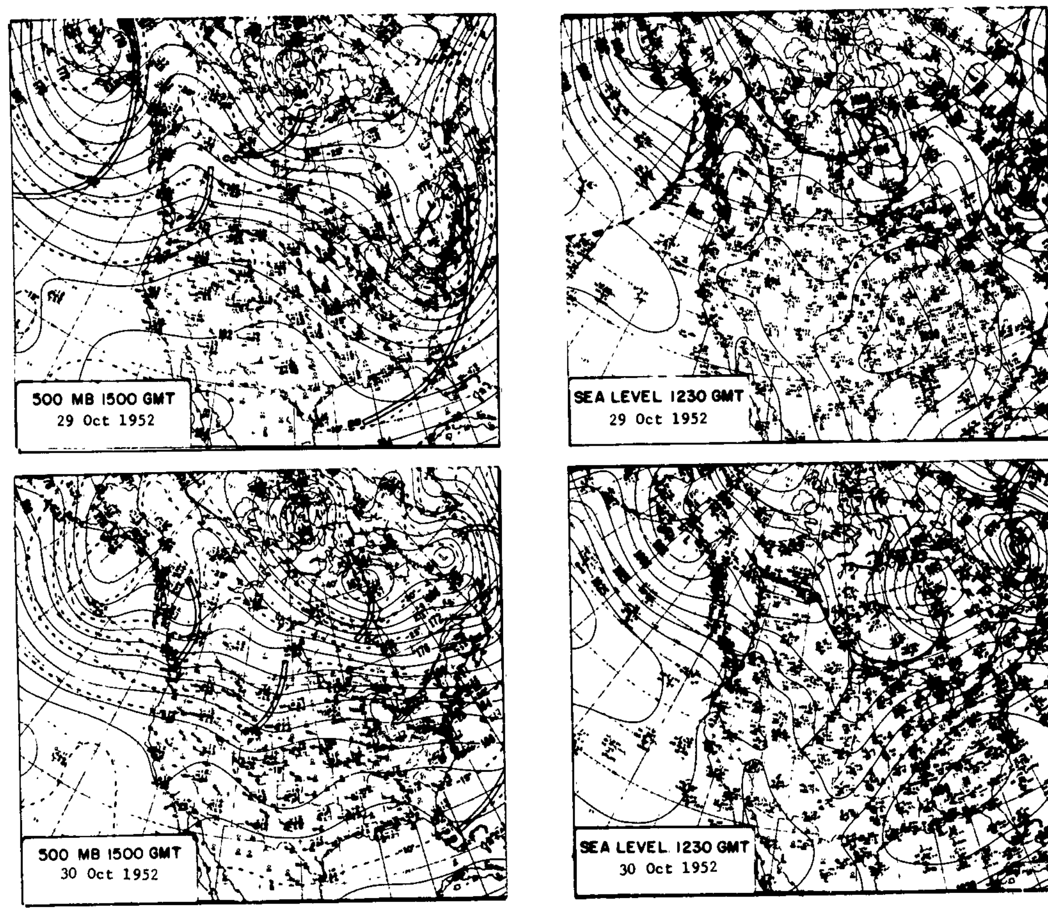


Figure 54. --Continued.

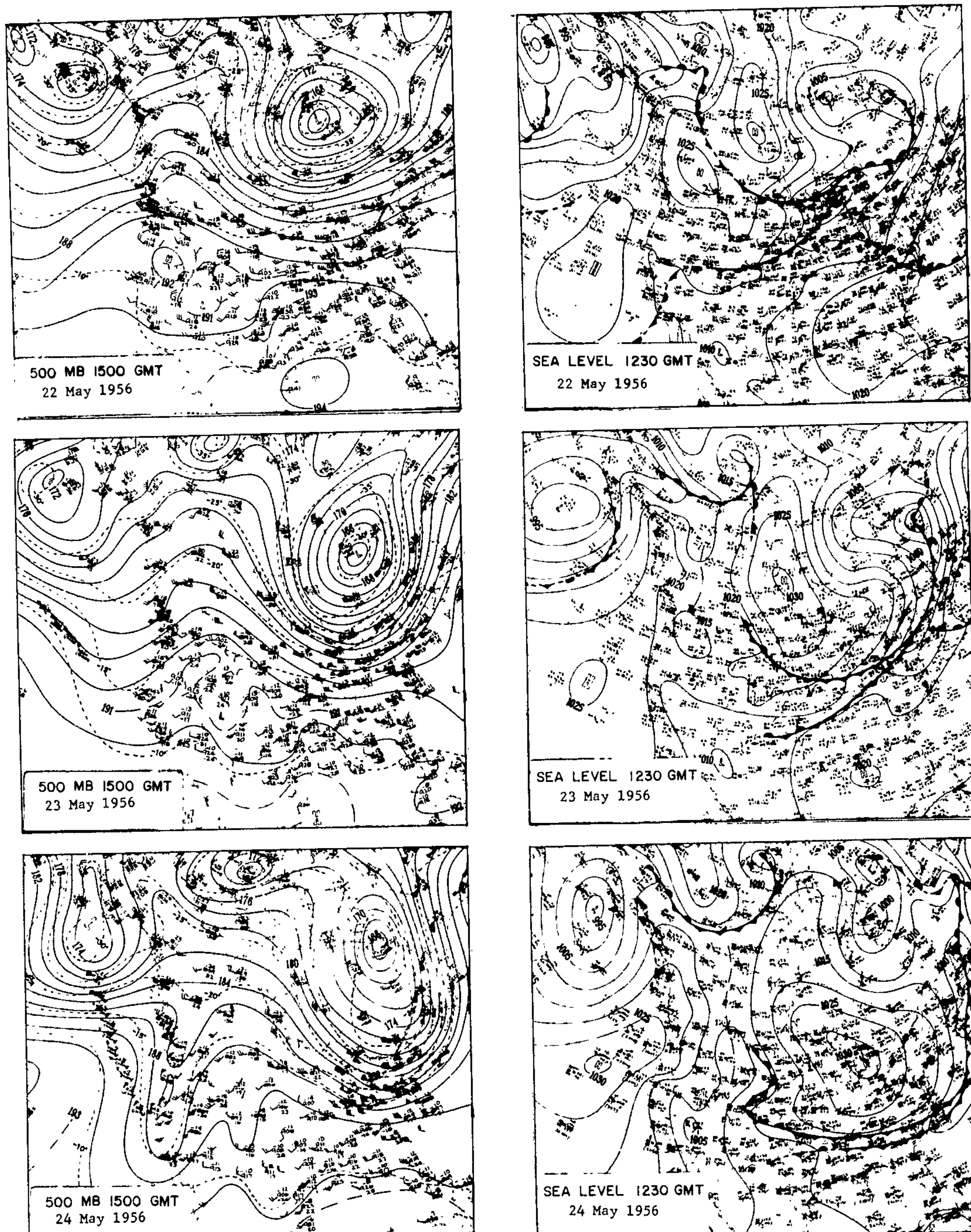


Figure 55.--Surface and 500 mb charts, May 22-26, 1956. High fire danger occurred in the pre-frontal area May 24 and 25.

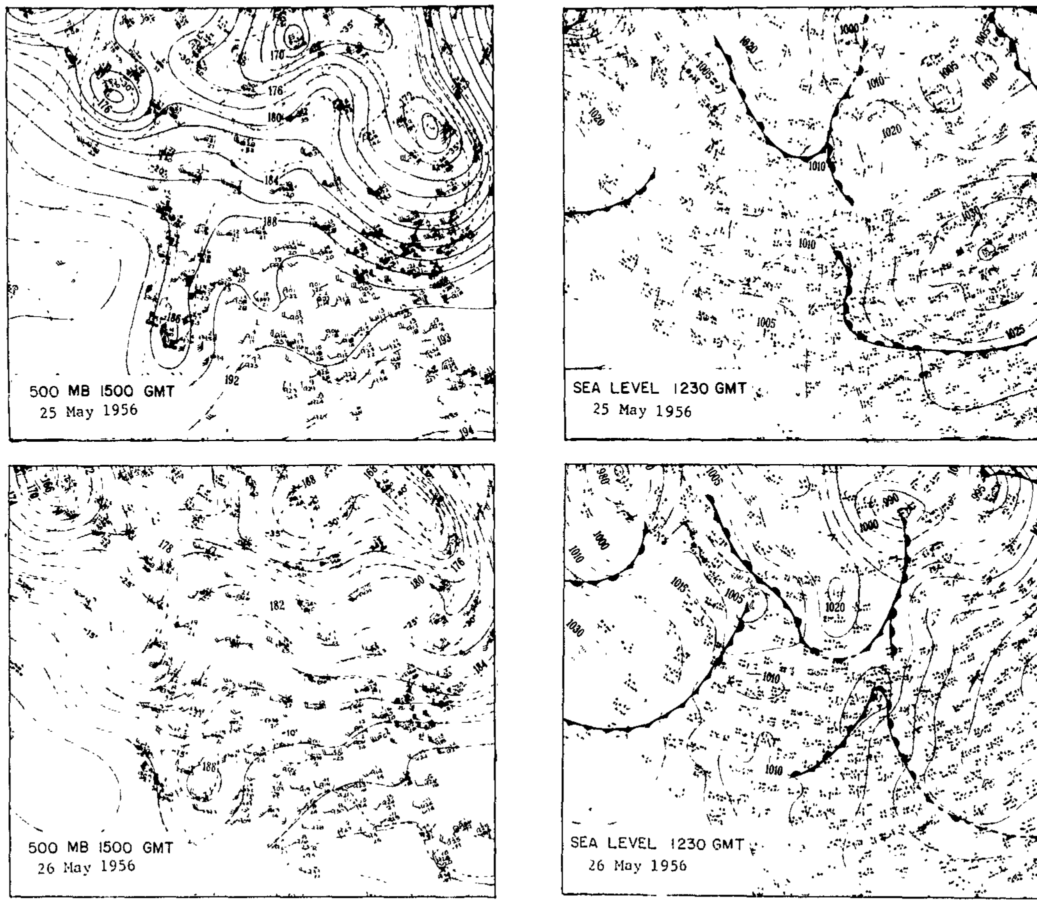


Figure 55. --Continued.

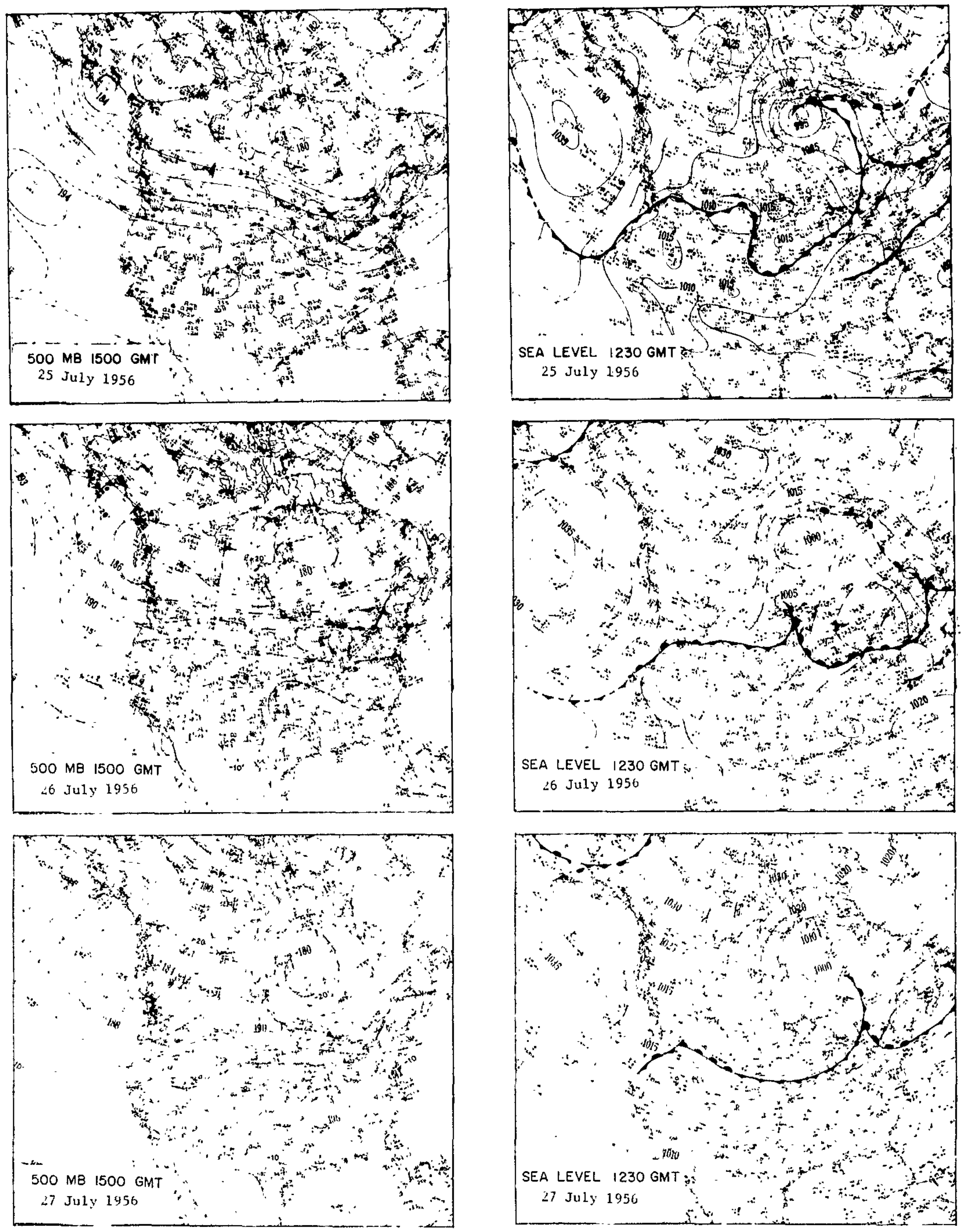
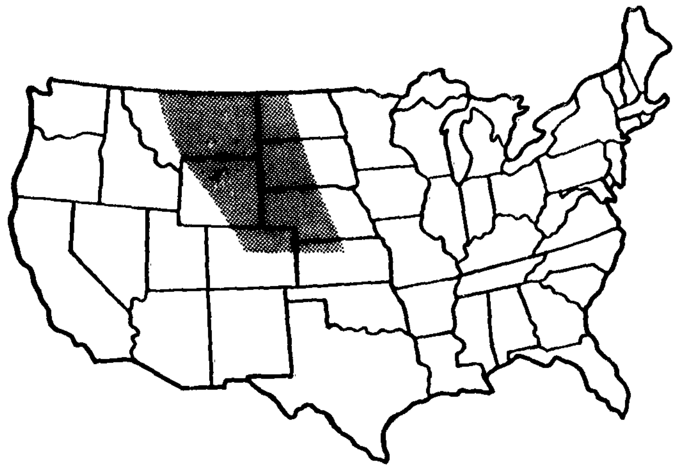


Figure 56.--Surface and 500 mb charts, July 25-27, 1956. High fire danger occurred at Des Moines July 26.



Northwest Plains Region

The Northwest Plains region includes the eastern two-thirds of Montana, the northeastern two-thirds of Wyoming, and roughly the western half of North Dakota, South Dakota, and Nebraska. The stations used to represent this region were Glasgow, Mont., Bismark, N. Dak., Rapid City, S. Dak., Casper and Lander, Wyo., and North Platte, Nebr. All of these stations are east of the Divide and experience the chinook effect in some degree. Usually the chinook effect is felt in a more marked degree in the area within 200 miles east of the Divide. However, in some instances, the chinook effect is felt as far east as Bismarck, Rapid City, and North Platte.

The fire season in the Northwest Plains region, in terms of both fire occurrence and the fire load index, usually extends from April through October. Relatively high fire danger in April and October usually results from strong chinook winds and low humidities, rather than from high temperatures. A fire load index of 22 or higher (the criterion for high fire danger) occurred 56 percent of the time during the 7-month fire season of the Northwest Plains. More than twice as many days of such high fire danger occurred in the months July through October as in April, May, and June. During the 10 years of study, 22 fires of Class E size (over 300 acres) burned in this region. Of 10 such fires selected at random, all started on days when the fire load index was 22 or higher (table 30).

A total of 1,253 days had a fire load index of 22 or higher. This resulted in a combined total of 2,303 station-days for the selected stations (table 31).

A study of the surface and 500 mb charts for the days of the high fire danger revealed three synoptic weather types. These were the Pacific High, the Northwest Canadian High, and the Hudson Bay High (tables 32 and 33).

Table 30.--Selected large fires[1], acreage burned, and associated fire load index at the nearest station, Northwest Plains region, 1951-60

Date	Location	Acreage burned	Fire load index
July 30, 1954	Custer National Forest	398	26
July 3, 1954	Medicine Bow N.F.	390	38
July 6, 1955	Medicine Bow N.F.	3,602	99
July 9, 1955	Medicine Bow N.F.	1,482	90
Aug. 16, 1955	Lewis and Clark N.F.	1,355	45
Oct. 23, 1955	Lewis and Clark N.F.	1,680	22
Sept. 2, 1956	Medicine Bow N.F.	973	99
Oct. 6, 1958	Black Hills N.F.	422	49
Sept. 8, 1959	Black Hills N.F.	4,501	35
Aug. 22, 1960	Black Hills N.F.	10,336	99

1/ Selected at random from a total of 22.

The Pacific High Type and Associated Chinook Effect

In the Northwest Plains, the Pacific High type was responsible for 99 percent of the days of fire load index over 22 during the 10-year period of 1951-1960 (table 32). This type brought the largest number of days of high fire danger to August, the second largest, and about the same numbers, to July and September, and the third largest, about the same numbers, to June and October (table 33). Most of the cases observed were associated with a chinook effect in some degree. This effect is the result of a surface trough east of the Continental Divide, a High to the east of the trough and another High to the west of the Divide.

The Pacific High type that affects the Northwest Plains region is one that starts as an extension of the east Pacific high pressure area into British Columbia and Washington. A cell breaks off from the main Pacific cell and pushes toward the Divide. Later, it moves southward along or to the east of the Divide.

The area of high fire danger is usually on the southwest or west side of the surface high pressure area to the east. In a few instances, the high fire danger has been observed on the south or southeast side of the Pacific cell as it moves down out of Canada--along or just behind a cold front as the cold air flowed out of the

Table 31.--Number of days with fire load index of 22 and above, by station, Northwest Plains region, 1951-60

Year	Glasgow			Bismarck			Rapid City		
	Fire load index equal to or greater than--								
	22	37	50	22	37	50	22	37	50
1951	11	1	0	1	0	0	15	4	1
1952	16	2	1	30	7	3	45	18	7
1953	13	2	1	12	2	0	29	8	3
1954	15	0	0	4	0	0	40	13	4
1955	24	7	2	28	6	3	35	16	15
1956	27	3	1	16	2	0	38	11	5
1957	16	2	1	8	0	0	11	2	0
1958	37	14	4	35	7	1	37	12	4
1959	40	8	5	44	13	6	49	22	12
1960	33	9	3	32	10	1	64	25	10
Total	232	48	18	210	47	14	363	131	61

Year	Casper			North Platte			Lander		
1951	39	11	9	1	0	0	16	8	5
1952	78	38	24	39	9	3	39	13	8
1953	90	47	24	36	14	5	38	19	11
1954	113	61	32	27	11	4	58	21	16
1955	102	64	58	45	14	4	59	17	12
1956	122	85	52	25	10	4	48	18	8
1957	59	20	11	1	0	0	10	3	1
1958	73	36	19	18	3	0	16	13	1
1959	87	44	34	17	5	0	36	12	7
1960	113	66	43	42	11	3	51	24	14
Total	876	472	306	251	77	23	371	148	83

Table 32.--Number of days with fire load index 22 and above, by synoptic type, Northwest Plains region, 1951-60

Year	Pacific High	Northwest Canadian High	Hudson Bay High
1951	53	2	0
1952	139	0	0
1953	134	0	0
1954	155	0	0
1955	130	0	8
1956	151	0	0
1957	79	0	0
1958	109	0	0
1959	129	0	0
1960	160	0	4
Total	1,239	2	12
Percent	98.9	0.2	0.9

Table 33.--Number of days with fire load index 22 and above by month and synoptic type, Northwest Plains region, 1951-60

Type	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Pacific High	13	22	27	78	106	143	186	226	198	165	62	13
NW. Canadian High	0	0	0	2	0	0	0	0	0	0	0	0
Hudson Bay High	0	0	0	0	4	0	8	0	0	0	0	0
Total	13	22	27	80	110	143	194	226	198	165	62	13

High over the Northwest Plains. In these cases, the period of high fire danger was not a long one because colder air, usually with higher humidity, moved into the area and lowered the fire danger. When a trough lies to the east of the Continental Divide over the Northwest Plains, a Pacific High is to the east, and the next Pacific High to the west of the Divide, the period of high fire danger is longer. During this period, the second High moves south and east out of Canada, and the air flowing into the low pressure area east of the Divide ahead of the high pressure cell is usually very dry and desiccating as a result of moving down across the Rocky Mountains.

If the second High takes a more easterly path with its center remaining north of the Canadian border, there will be considerable upslope motion on the south and west side of the High causing low clouds, some light precipitation, and very low fire danger.

The significant periods of high fire danger are brought on by the Pacific High moving down along the Divide and then to the south and east over Montana and the Dakotas or Nebraska. A short period of high fire danger might be experienced on the southeast side of the High for a few hours as cooler air flows out following a cold front. But the periods of significant fire danger develop after the high pressure center at the surface has moved on to the south and east. At the same time, the ridge aloft is usually just to the east of the Divide and there is a marked trough just off the West Coast. There were, however, a few isolated cases in which the ridge aloft was to the west, over the eastern Pacific. Usually the upper flow during the period of high fire danger is from the southwest to west on the west side of the upper ridge and ranges from 30 to 70 knots at 500 mbs. This upper-flow pattern provides an ideal condition for a surface trough to develop to the east of the Divide on the west side of the surface High.

The center of the circulation aloft is usually over the southern Rocky Mountains or the Southwest. The warm ridge aloft is a favorable area for subsidence. Some of the subsided air may be caught in lower level circulations and carried across the Northern Rockies. On the east side it flows downward as a chinook wind into the surface trough. The dry air is caught up in the southerly flow on the east side of the trough and is carried toward the north. If the location of the trough at the surface is to the north, over Montana, then the dry air will be carried into eastern Montana and North Dakota. If the surface trough is farther to the south over Wyoming, then the dry, warm air will be carried farther east into eastern Colorado, Nebraska and South Dakota. In this situation, the humidity will often fall to below 10 percent, and occasionally below 5 percent. The winds at the surface will be out of the southwest to west 15 to 25 mph. The effect of the subsidence out of the high pressure area aloft plus the chinook effect down the east side of the Rocky Mountains will result in very high temperatures during the summer months. Under the influence of this pattern, the 1/2-inch-stick moisture content has been measured

down below 3.0 percent. If high temperatures occur without the effect of the southwesterly flow aloft across the Rocky Mountains, the fire danger does not rise as high because of the lighter surface winds experienced.

The flow pattern aloft may be meridional, zonal, or short-wave train type. Meridional patterns tend to occur during July and August and zonal patterns in fall, winter, and spring. The ridge, on the average, is oriented north-south across the Plains of southern Canada and the United States at about 100°W. Even under the influence of zonal flow when a trough exists to the east of the Divide, the chinook effect is well marked. Under all three types of upper flow, the component is from the southwest, and ranges from 30 to 70 knots. The average location of the trough is at about 128°W.

The Pacific High type is illustrated by the surface and 500 mb charts for the period of August 22-26, 1952 (fig. 57). The mean upper trough was located just off the West Coast during all of the period. Short waves were moving out of the trough and across the Pacific Northwest. The upper flow was from the southwest 30 to 40 knots. The surface anticyclone had broken off from the Pacific high pressure cell, moved eastward,-and had reached Lake Superior by August 22. By August 24, high fire danger was brought to the Northern Rocky Mountains in the trough on the west side of the Pacific High, now centered over Ohio. August 25, the trough had intensified on the east side of the Rocky Mountains. The flow at the surface was from the southwest, 15 to 25 knots. The upper-air flow continued out of the southwest across the Divide. Under this combination of circulation oonditions the fire load index climbed to 50 to 60 at stations within 200 miles or so of the Divide. The temperature at stations to the east of the Divide were of the order of 80 to 90°, and the humidities 20 percent. The moisture content in the 1/2-inch-sticks, in this instance, ranged from 3.5 to 4.5 percent. Farther out on the plains, at Rapid City, the fire load index did not rise until the following day, August 26 as the trough moved farther to the east and as the Pacific High receded farther to the southeast.

The maps at the surface and aloft, for August 26, 1952, should be studied closely for two effects. The most important is the location of the surface trough over the Plains in North Dakota and Wyoming. This caused the area of maximum southerly flow of surface wind to be carried farther to the east into the Dakotas and Nebraska. The fire load index climbed to 23 at Rapid City and the temperature to 83, under a southerly flow at the surface of 20 knots. The second aspect to be noted on this date was the effect of the position of the eastern edge of the next Pacific High as it began to break off and push across the Divide. Under the influence of the air flowing out of this Pacific High eastward across the Divide and down the east side, the fire danger remained high along the east slopes of the Divide.

The upper-air flow was marked by short waves moving out of the mean trough off the West Coast and continuing eastward around the semi-permanent ridge over the northern Plains. The flow aloft continued from the southwest to west under this circulation pattern. August 25, the Northwest Plains lay just ahead of a short-wave trough aloft moving to the northeast. Warmer air ahead of the upper trough added to the chinook effect as the air flowed down the east side of the Divide. August 26, the region began to come under the influence of slightly cooler air from the west, behind the upper short-wave trough as it moved eastward across the Divide.

Prediction.--To anticipate the favorable condition for marked warming east of the Divide, the upper-air pattern should be studied. The most favorable flow is one in which a well-established trough is situated off the West Coast and a semi-permanent ridge of high pressure to the east of the Divide. This pattern will cause a southwesterly flow across the Divide. At the surface, a strong ridge must be building over the eastern Pacific and into the western part of Canada. As soon as the ridge breaks off over British Columbia, it should be watched for movement to the southeast across the Divide. Then the establishment of the strong surface trough to the east of the Divide combined with a strong west to southwest flow aloft should be looked for.

A map of the average upper-air flow (fig. 58) shows the central streamline of all the Pacific High cases. The flow at 500 mb is such that it will carry warm air from the southwest to the northeast, across the Divide, permitting a foehn effect down the east slopes of the Divide.

The only exception to this flow pattern at 500 mb was for the one case of the Canadian High type. For this one case, the ridge aloft was west of the Rocky Mountains in northwestern United States and western Canada. This orientation still supported a chinook effect down the east side of the Divide out onto the Plains.

Table 34 provides some average values of several weather elements and fire load indexes that might be of value as forecasting guides during this type.

The breakdown of this type comes with a strong, short-wave trough aloft moving out of the main trough off the West Coast. The moving trough may take the form of a closed Low through the Pacific Northwest and to the east of the Divide. When a short wave trough moves through the region, the upper flow may change to a pattern in which the West Coast trough moves inland along or to the east of the Divide. Then cooler air flows in from the northwest and decreases the fire danger. When a closed Low moves out of the West Coast trough, precipitation is often carried to the east of the Divide and lowers the fire danger. The dissipation of the West Coast trough and its movement eastward are indicated by rapid lowering of the 500 mb surface along the West Coast.

Table 34.--Weather and fire load index averages for high fire danger days during the Pacific High type, June through September, Northwest Plains region

Quadrant	Temperature	Relative Humidity	Prevailing wind direction	Wind speed	Fire load index
	°F	Percent		Mph	
West	80-90	5-15	West to SSW	15-30	1/ 40-70
Southeast	70-80	10-20	SW to NW	15-30	30-50

1/ Many cases with fire load index of 99.

Henry's 6/ rule is of some value in giving the first indication that a closed Low may move eastward from the West Coast trough. This rule states that if a center of 24-hour height-fall approaches to within 1,200 miles to the northwest of the center of the offshore closed Low, then the closed Low will move out to the east or northeast.

Another development that brings an end to the high fire danger over the Northwest Plains occurs when an area of high pressure, usually of Pacific origin, moves down over Alberta. This results in upslope winds from the northeast to southeast and often causes the development of low clouds and some light precipitation.

The period of high fire danger with the Pacific High type is usually dependent upon the slow-moving high pressure cells at the surface, combined with the strong low-pressure trough between them just to the east of the Divide. This combination, together with the strong upper flow of subsiding air from the southwest across the Divide, sets the stage for strong, dry southwesterly surface winds that carry the high temperatures to the north. As soon as the upper flow goes to a rapid zonal type, the day-to-day changes usually take place too rapidly for marked heating and drying to take place.

The Northwest Canadian High and the Associated Chinook

Less than 1 percent of the cases of high fire danger over the Northwestern Plains was associated with a Northwest Canadian High. Even so, this is an interesting type and should be explained. The surface and upper-air maps for the period October 25-31, 1952 show the only case of this type in the ten years of records (fig. 59). On October 25 the Canadian High was well developed over western Canada. The flow to the southeast out of this cell was drawn into an area of

6/ Unpublished master's thesis on file at University of Chicago.

low pressure to the east of the Divide in Alberta. Had the surface High been situated over the Pacific Northwest and the trough to the east of the Divide in Montana and Wyoming, ideal conditions would have been present for a strong Chinook to the lee of the Divide in Montana and Wyoming. In this case the circulation centers were too far north, and, for this reason, the chinook effects were not felt to the east of the Divide in Montana and Wyoming, but only in Alberta. However, as the Northwest Canadian High moved to the east of the Divide, October 29 and 30, it was followed by another high pressure area of Pacific origin, and accompanied by a strong flow aloft from the west. Conditions were then established for the chinook effect to be felt east of the Divide. This brought a fire load index of 52 to Casper October 29, a temperature of 70, a relative humidity of 12 percent, a 1/2-inch-stick moisture content of 5.6 percent, and a westerly wind of 20 knots. The following day, the high fire danger appeared farther to the east, behind the surface High and ahead of the surface trough. The breakdown of this type was brought on by the movement across the region of a strong short-wave trough that caused the eroding of the upper ridge. The upper flow then shifted to a more zonal pattern. This one case was a strong meridional pattern with the upper ridge located, initially, to the west of the Divide in Canada. The ridge was gradually eroded away by short-wave troughs which caused it to be depressed gradually to the south and east. The flow then became more zonal and allowed cooler air to be brought into the Northwest Plains.

The Hudson Bay High Type

A little over 1 percent of the high fire danger days was associated with a Hudson Bay High at the surface. This type usually brings high fire danger farther to the east over the Northeastern Plains, and only rarely to the Northwestern Plains.

The Hudson Bay High type may or may not be associated with chinook winds, but in any case when dry, subsiding air reaches the surface in the Northwestern Plains it produces high fire danger in that region. Because of the general slope to the topography in the Northwestern Plains the air mass within the Hudson Bay High is not involved in the high fire danger. This air enters the region with easterly or southeasterly flow which is upslope and not conducive to high fire danger. The high fire danger is usually found in the warm sector of a Low passing by to the northwest or north. If the flows aloft and in the warm sector have a westerly component, the circulation pattern is favorable for chinook winds over and down the east side of the Rocky Mountains. If the flow aloft has a westerly component, but the flow in the warm sector is southerly, warm, dry air from aloft may still reach the surface in the warm sector. Apparently subsiding air from aloft is caught up in the southerly surface flow and carried to the north.

The surface and 500 mb maps for the period July 8-13, 1955 (fig. 60) illustrate the latter type. July 8 the Hudson Bay High began moving

southward out of Canada west of Hudson Bay. By July 9 it reached into the Northern Plains. The next day the center of the circulation was over Lake Winnipeg. A broad, low pressure trough developed over the Rocky Mountains. At 500 mb the southern branch of the split flow was out of the southwest at 30 to 50 knots. This flow across the Divide was favorable for subsidence east of the Divide. The highest fire danger occurred in the warm sector of the advancing cyclone where subsided air apparently was caught up in the southerly low-level flow. The fire load index reached 99 at Casper and 35 at Lander. The hot, dry air appeared to be air that had originated at high levels in the atmosphere. The temperature at Casper was 96, the humidity 3 percent, and the wind south-southwest 27 knots. The area of high fire danger advanced to the east July 11 as the surface High moved to the east. Previously, as the Hudson Bay High moved to the south on July 9 and 10, it provided a lifting mechanism over the Dakotas to lift the flow of moist air from the Gulf of Mexico. This resulted in low fire danger in that area as a result of the high humidity accompanying widespread rain.

Prediction.--This type develops with the presence of a blocking ridge aloft along and to the east of the Divide in Canada. The resulting northerly component in the upper flow over the Plains of Canada carried the Hudson Bay High to the south over the northern Plains of the United States. At the same time a split flow is present over the northwestern part of the United States. This results in a strong flow from the southwest across the Divide area of Colorado to Montana and favors the subsidence necessary to produce high surface temperatures and dry air.

If the Hudson Bay High moves into the northern Plains under the influence of a strong upper trough developing over central United States, the high fire danger will be observed farther to the east over the northern Plains and the Lake States. No cases of this type brought widespread high fire danger to the Northwest Plains region during the ten years studied. This type will be effective from the Northeast Plains eastward.

The end of the Hudson Bay High type with a blocking ridge is brought on when the ridge aloft breaks down and the upper flow shifts to a more zonal pattern. This breakdown is indicated by marked lowering of the 500 mb surface over the Rocky Mountain area of British Columbia and Alberta. At the same time that heights are falling over the interior of Canada, heights are rising over the Gulf of Alaska.

There were only two cases of the Hudson Bay type during the ten years of study. One of these cases was during May, the other during July. As can be noted from the values cited for the case of July 10, the fire load index values can be very high near the Divide, but quite low farther out on the Plains under the influence of air with a Gulf trajectory.

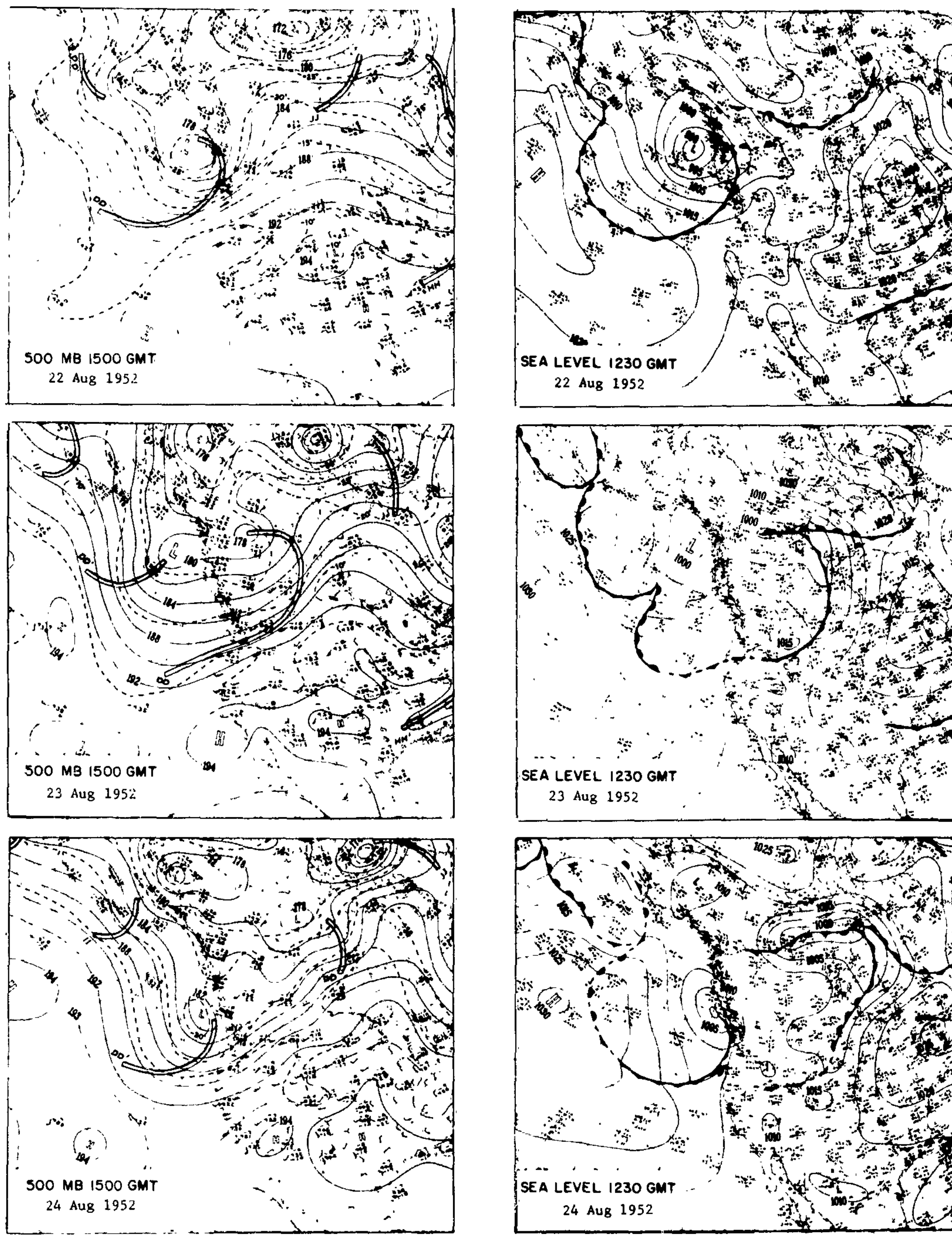


Figure 57. --Surface and 500 mb charts, August 22-26, 1952. High fire danger occurred on the southwest side of the High to the lee of the Divide August 25.

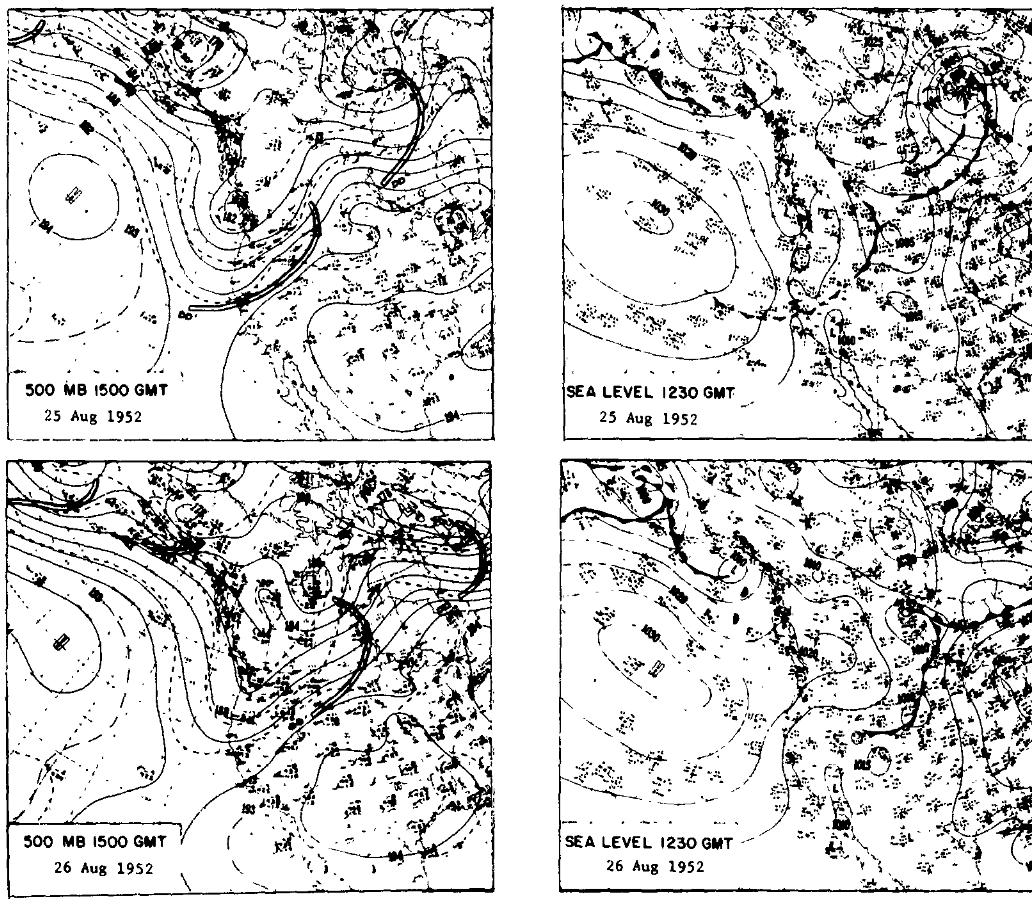


Figure 57. --Continued.

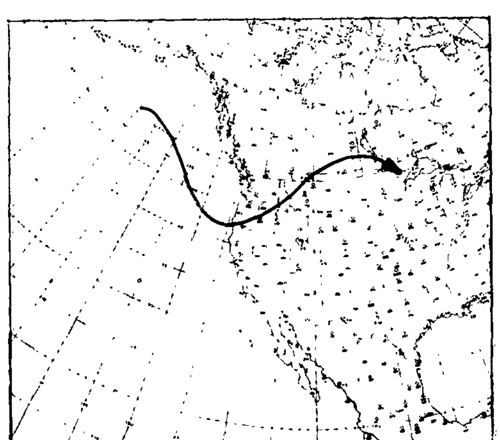


Figure 58. --Plot of ridge and trough points for the short-wave train cases of the Pacific High type.

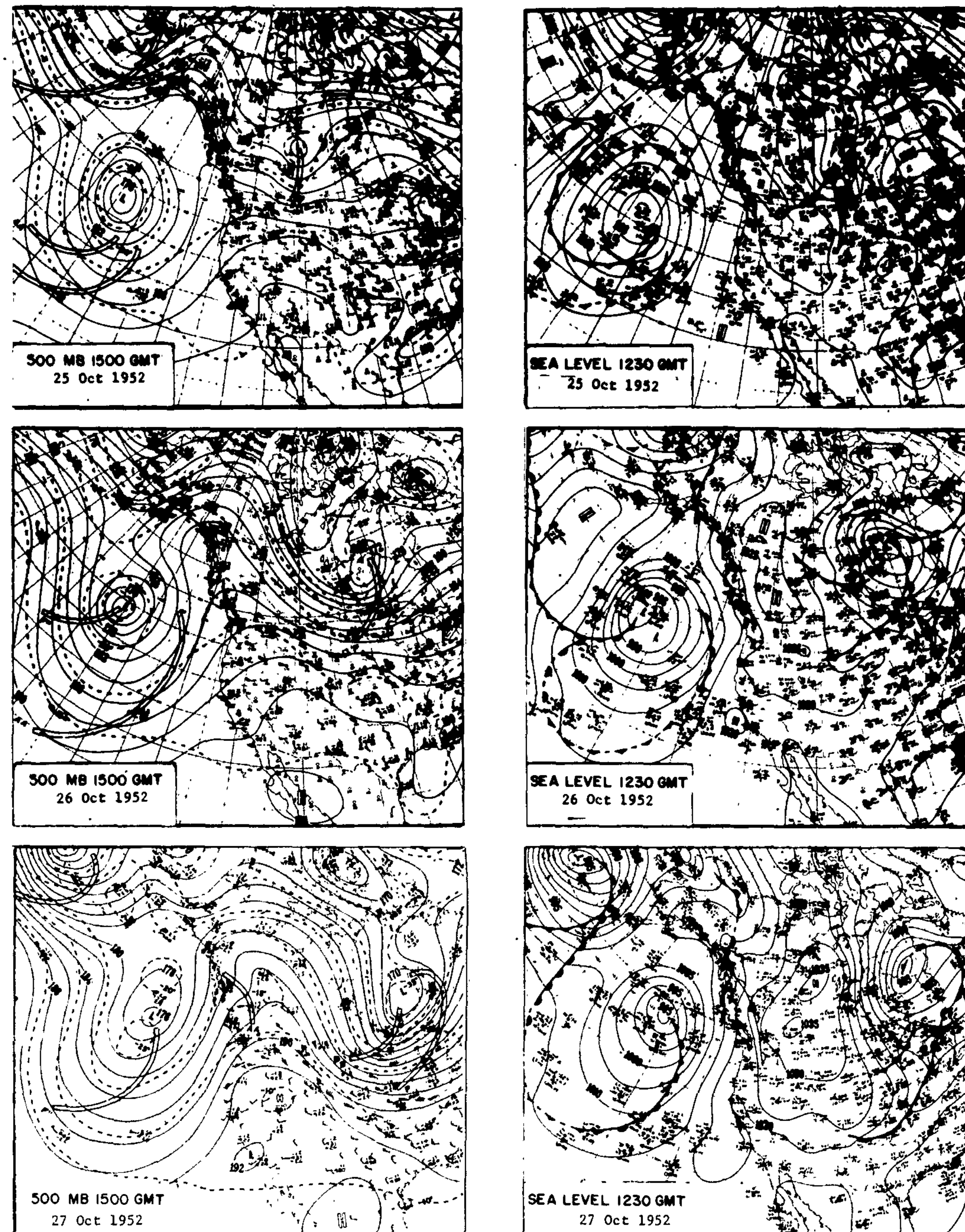


Figure 59. --Surface and 500 mb charts, October 25-31, 1952. High fire danger occurred on the southwest side of the Northwest Canadian High October 29 and 30.

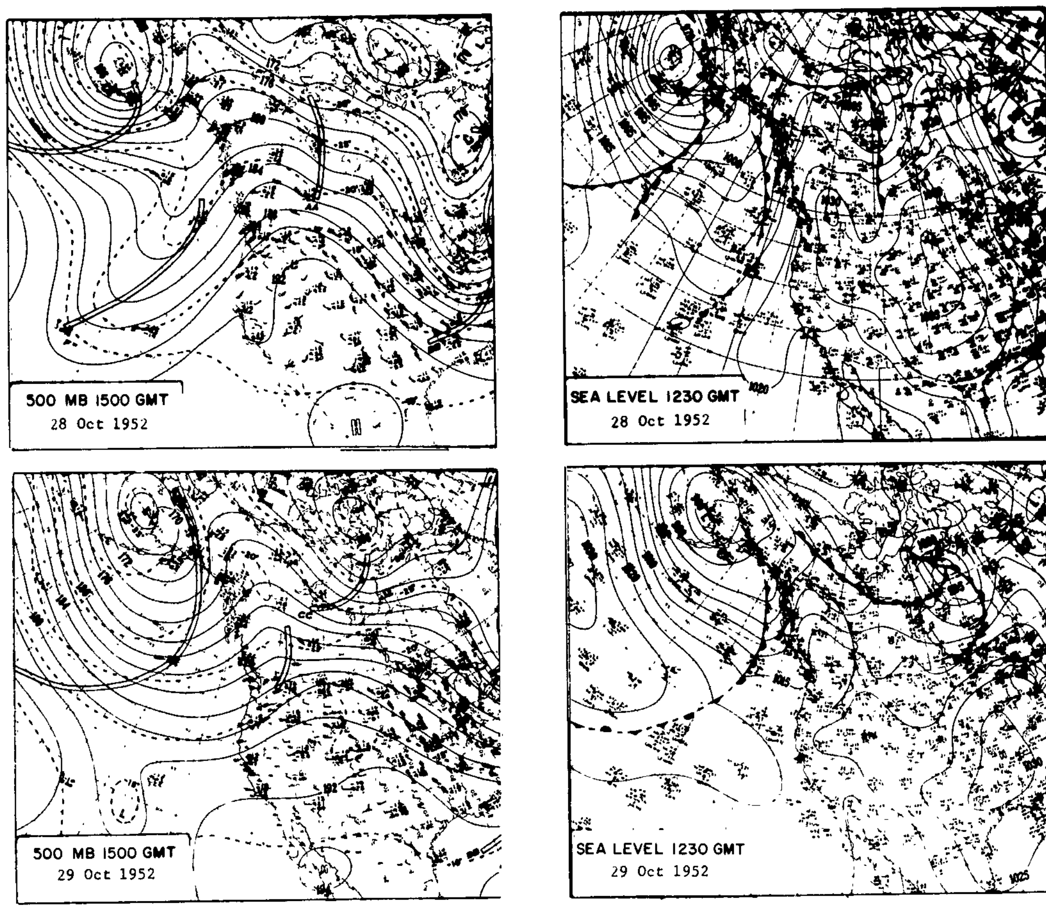


Figure 59. --Continued.

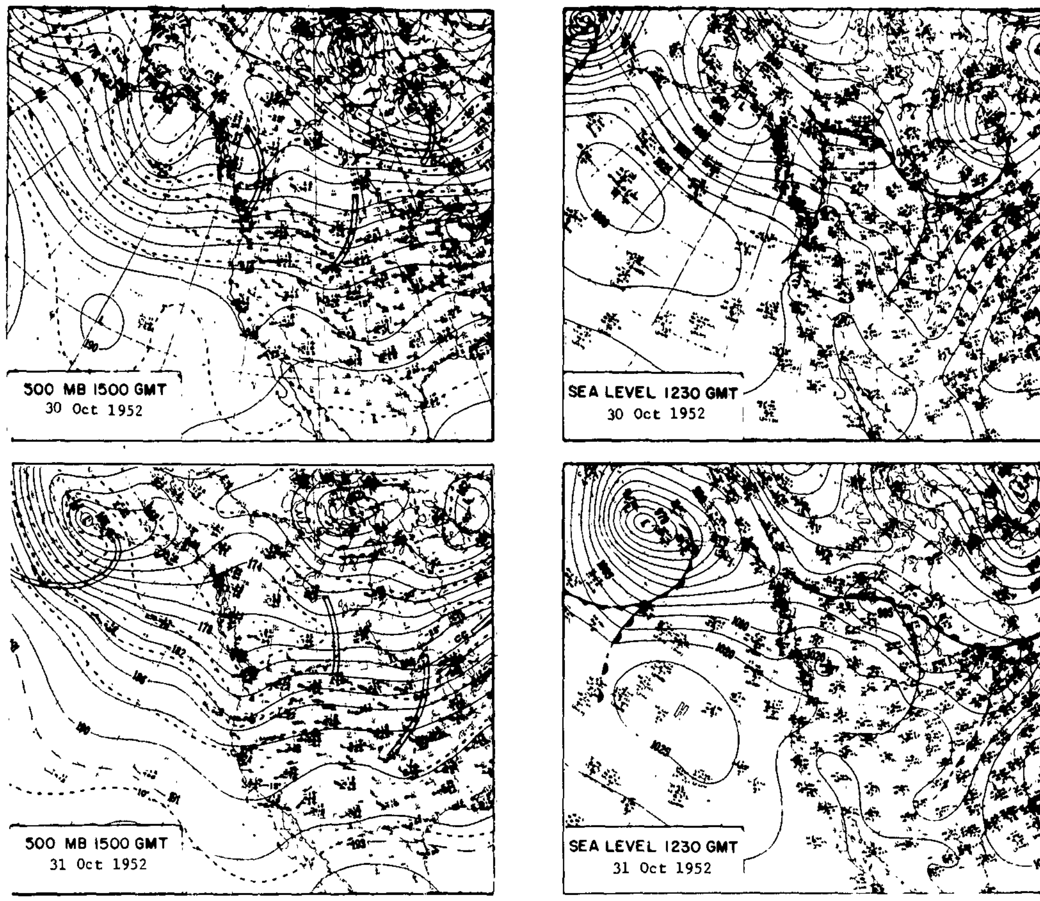


Figure 59. --Continued.

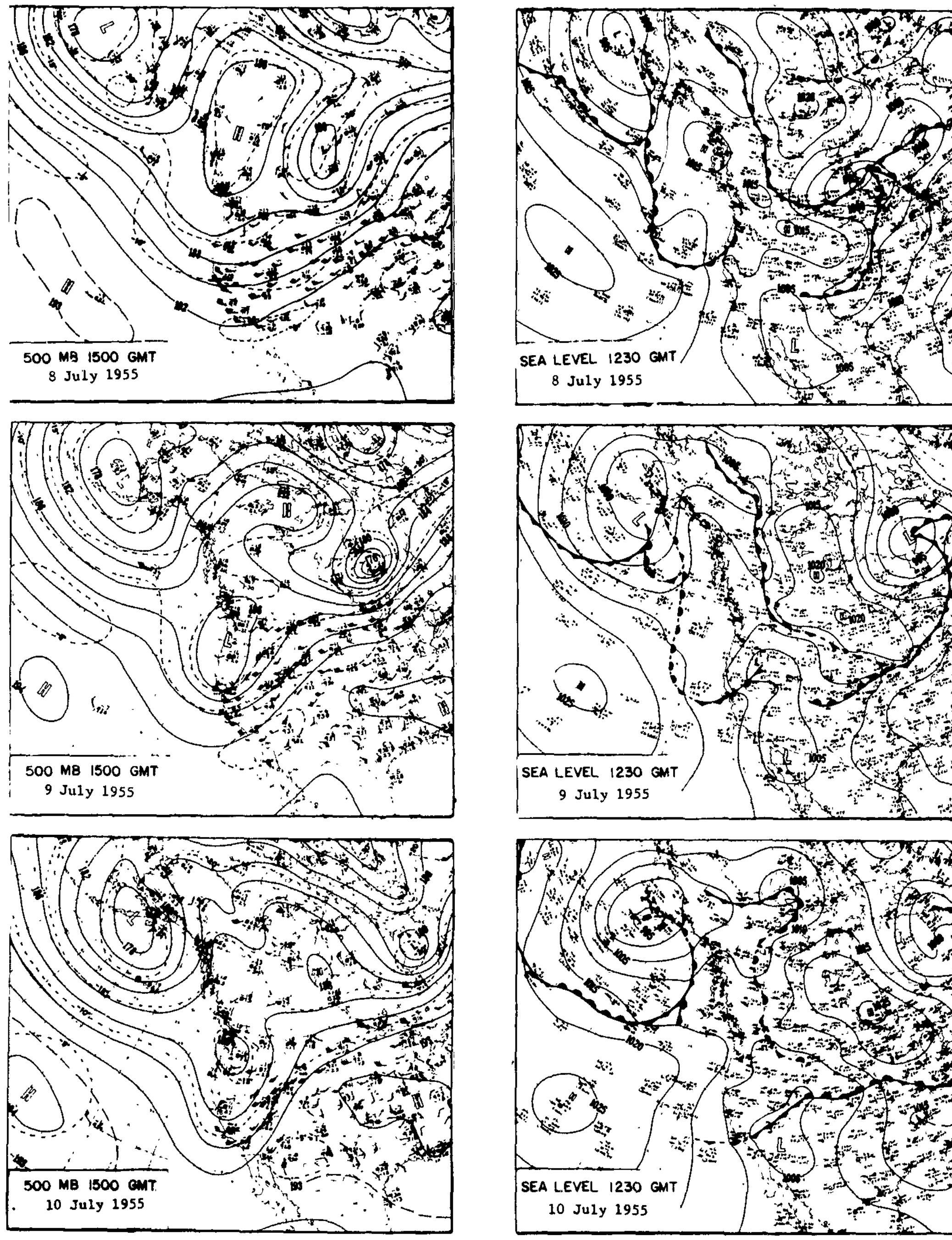


Figure 60. --Surface and 500 mb charts, July 8-13, 1955. High fire danger occurred on the southwest side of the Hudson Bay High July 10 just east of the Divide and July 11 farther to the east.

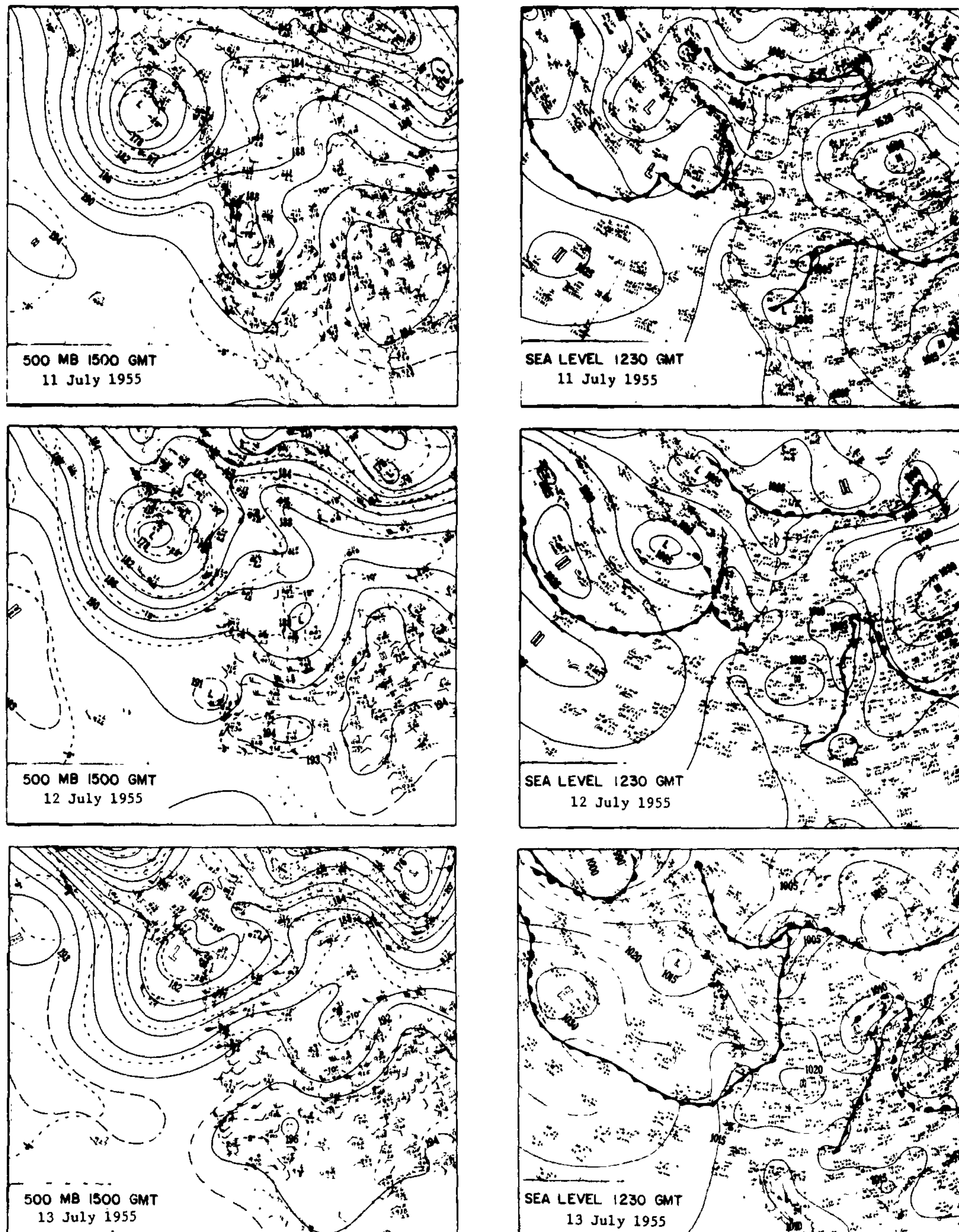
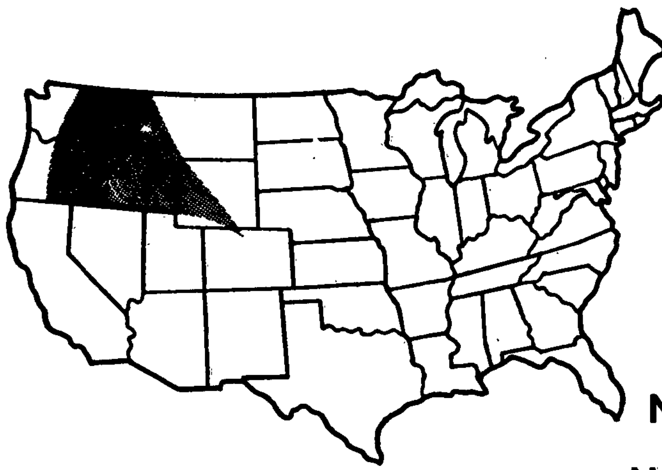


Figure 60. --Continued.



Northern Rockies and Northern Intermountain Region

The Northern Rockies and Northern Intermountain region includes southeastern Washington, Oregon east of the Cascades, Idaho, the western third of Montana, and the southwestern third of Wyoming. The stations used to represent this region were Yakima and Spokane, Wash., Redmond and Pendleton, Oreg., Boise and Pocatello, Idaho, and Kalispell, Missoula, and Dillon, Mont.

The fire season, in terms of both fire occurrence and high fire load index, usually extends from June through October over the southern half of the region and from July through September over the northern half. There were, however, isolated cases of high fire danger as early as March and as late as November. These cases generally are not important because the weather is rather cool during these periods. Over the northern part of the region the fire load index was 22 or higher 16 percent of the time in July, August, and September. Over the southern part of the region, an index of 22 or higher occurred about 20 percent of the time for the five months June through October.

In this region as in the Northwest Plains, cases were selected for investigation which had a fire load index of 22 or higher at any station. There were 86 fires of Class E size (over 300 acres) during the 10-year study period. Of 20 fires selected at random (table 35), 4 started on days when the fire load index was below 22. A study of the weather conditions and the fire load indexes on the days just preceding and following the days on which the fires started showed that even though the fire load index was not 22 or higher, the ignition index was significantly high on the day of the fire and the fire load index had been high just previous to the fire.

Table 35.--Selected large fires and associated fire load index at the nearest station, Northern Rockies and Northern Intermountain region 1951-60[1]

Date	Location	Acreage burned	Fire load index
August 2, 1951	St. Joe National Forest	384	25
Sept. 14, 1951	Boise N.F.	384	7
Sept. 30, 1952	Lolo N.F.	860	31
Oct. 8, 1952	Boise N.F.	720	7
June 30, 1953	Shoshone N.F.	14,000	45
July 19, 1953	Gallatin N.F.	1,170	48
Sept. 16, 1953	Payette N.F.	447	17
August 16, 1955	Lewis and Clark N.F.	1,355	29
Sept. 5, 1955	Boise N.F.	8,310	33
January 19, 1956	Bridger N.F.	1,003	22
Sept. 19, 1956	Salmon N.F.	340	29
July 26, 1957	Boise N.F.	525	35
Sept. 26, 1957	Caribou N.F.	1,160	50
July 28, 1958	Boise N.F.	7,000	16
August 7, 1958	Kootenai N.F.	1,282	29
August 3, 1959	Boise N.F.	9,015	42
Sept. 13, 1959	Gallatin N.F.	445	27
July 13, 1960	Boise N.F.	2,740	52
Sept. 19, 1960	Lolo N.F.	1,230	22
July 19, 1960	Payette N.F.	11,967	52

1/ Selected at random from a total of 86 Class E fires.

Table 36.--Number of days with fire load index 22 and above, by station, Northern Rockies and Northern Intermountain region, 1951-60

Year	Yakima			Spokane			Redmond			Pendleton			Boise		
	Fire load index equal to or greater than--														
	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50
1951	29	1	0	14	0	0	27	1	1	27	4	0	26	1	1
1952	29	3	0	11	2	0	8	2	0	10	1	0	22	2	0
1953	19	1	1	3	0	0	14	4	3	21	9	4	47	10	2
1954	22	2	0	2	0	0	7	1	0	7	3	0	52	18	6
1955	13	2	0	13	4	0	25	1	1	36	7	1	43	8	4
1956	10	0	0	12	2	0	9	1	0	34	14	3	23	0	0
1957	2	0	0	5	0	0	2	1	0	14	0	0	18	3	1
1958	19	3	1	18	0	0	7	0	0	34	7	1	12	2	0
1959	29	4	2	18	3	1	17	2	1	30	7	5	27	7	1
1960	14	1	0	37	6	1	13	2	1	38	14	5	48	15	4
Total	186	17	4	133	17	2	129	15	7	251	66	19	318	66	19

Year	Pocatello			Kalispell			Missoula			Dillon		
1951	51	16	5	6	0	0	7	1	1	26	8	1
1952	64	20	9	3	0	0	10	2	1	30	11	2
1953	83	30	14	11	3	3	17	2	0	46	24	8
1954	90	50	25	3	0	0	8	1	0	47	18	8
1955	73	32	18	16	8	2	16	0	0	38	11	4
1956	93	33	12	9	3	1	7	1	0	39	17	8
1957	57	29	15	6	1	0	8	2	0	22	10	7
1958	60	21	10	18	3	0	4	0	0	20	6	4
1959	77	35	18	16	5	1	11	0	0	15	3	1
1960	89	37	16	15	5	0	16	2	0	19	2	0
Total	737	303	142	103	28	7	104	11	2	302	110	43

During the period 1951-1960, a total of 1,025 days had a fire load index of 22 or higher, producing 2,265 station-days of high fire danger (table 36).

A study of the surface and 500 mb charts for the days of high fire danger revealed two significant synoptic weather types: the Northwest Canadian High and the Pacific High. The Pacific High was responsible for the greatest number of days, and the greatest frequency of high fire danger (tables 37 and 38).

Table 37.--Number of days with fire load index 22 and above, by synoptic type, Northern Rockies and Northern Intermountain region, 1951-60

Year	Pacific High	Northwest Canadian High
1951	127	5
1952	100	1
1953	118	0
1954	107	0
1955	112	1
1956	108	0
1957	69	0
1958	79	0
1959	89	0
1960	104	5
Total	1013	12

Table 38.--Number of days with fire load index 22 and above by months and synoptic type, Northern Rockies and Northern Intermountain region, 1951-60

Type	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Pacific High	0	1	6	46	78	129	215	218	186	109	21	4
NW. Canadian High	0	0	0	5	0	3	0	3	0	1	0	0
Total	0	1	6	51	78	132	215	221	186	110	21	4

The Pacific High Type

The Pacific High type was responsible for 99 percent of all the cases of fire load index 22 and higher. This type is most frequent during the months of June through October but it is not infrequent during April and May. It produced high fire danger only infrequently during March and November, and on only four occasions in December during the 10-year period.

The Pacific High that affects the Northern Intermountain and Rocky Mountain region is one that starts as an extension of the Pacific ridge into British Columbia and Washington. This ridge breaks off from the main Pacific cell and pushes toward the Divide. Later it moves southward along the Divide or to the east of the Divide.

The area of high fire danger is usually on the southwest or west side of the surface High. In some instances, particularly in the area east of the Cascades, high fire danger is observed in the post-frontal area on the leading side of the High if the frontal passage is dry. Such dry fronts can cause a very serious fire situation with surface winds of 20 to 40 mph for a brief period and relative humidities of 15 to 25 percent. This situation occurs more frequently in the Central Intermountain region to the south. The period of high fire danger lasts until winds become lighter and the air becomes colder farther to the rear of the front. The occurrence of precipitation with the frontal passage appears to be related to the trajectory of the Pacific High. If the High has a trajectory across southwest Canada there is little chance of shower activity in the frontal zone. If the high moves across Washington and Oregon there is about a 50 percent chance that some light precipitation will fall, particularly in the north.

The period of high fire danger usually develops as the Pacific High moves on to the east and south and causes the circulation over the region to shift into the south and southwest on the west side of the High. The duration of the period of high fire danger with this type ranged from 2 to 8 days. The average was 2 to 4 days. The shorter periods of high fire danger were observed under the influence of a zonal flow aloft, when short-wave troughs and ridges moved through the region quite rapidly. This is usually a spring or late fall pattern. During the summer months a meridional pattern is more common and longer periods of high fire danger are observed, sometimes lasting as long as 13 to 19 days. With the meridional pattern, the ridge aloft becomes stagnated over Arizona and Utah and produces a south to southwest flow over the region.

Under the ridge aloft a thermal trough develops at the surface between the High to the east and an extension of the Pacific ridge inland over British Columbia, Washington, and Oregon. This combination of a meridional ridge aloft and a thermal trough at the surface is a hot, dry type. Subsidence takes place in the ridge aloft, particularly on its east side. Apparently some of the sinking air becomes caught

in the southerly circulation at lower elevations between the High to the east and the thermal trough. It is not unusual in this situation for humidities to fall below 10 percent. Surface winds are out of the south at 16-25 mph. The combination of high temperatures, low humidities, and southerly winds will cause fuels to dry out rapidly. The moisture content of 1/2-inch fuel moisture sticks may fall below 2 percent.

On the average for meridional cases, the upper ridge is oriented nearly north-south at longitude 105-110°W, and the trough is off the Pacific Coast (fig. 61). The upper-air flow over the region with this pattern is from the southwest at 30 to 70 knots.

Only a few cases of zonal flow aloft were observed. Although the amplitude is much smaller, a ridge is located to the east of the region during high fire danger as it is in the meridional cases.

The maps for August 29 to September 3, 1955, illustrate the Pacific High type with meridional flow aloft (fig. 62). This was a case with pronounced meridional flow. There are many cases in which the amplitude of the pattern aloft is not quite so large and the ridge is then slightly farther to the east. The sequence of events, however, is similar.

At the surface a High of Pacific origin moved through British Columbia and by August 30 was centered over southern Saskatchewan. Another extension of the Pacific ridge was protruding into British Columbia and Washington. A thermal trough had developed over California and Nevada and extended northward into eastern Washington and eastern Oregon.

The ridge aloft, located at about 115°W August 29, was drifting slowly eastward. At 500 mb the center of the circulation was over Nevada and Utah August 30. The subsiding air from the east side of the ridge could be caught in the lower level flow around the High and carried northward in the southerly circulation around the High's west side. August 30 the fire load index rose to 99 at Boise, 45 at Spokane, and 26 at Pendleton. The temperature at Boise was 103°, at Spokane 91°, and at Pendleton 91°. The humidity at Boise was 6 percent, the wind south 17 mph, and the computed fine fuel moisture 1.5 percent.

On the following day the crest of the ridge aloft had moved eastward slightly and the surface High moved to Minnesota. The thermal trough also moved slightly eastward and brought high fire danger to the Northern Rockies. No definite region-wide break in the high fire danger occurred in this case. Fire danger remained high at most stations on September 1 as a weak nose of the Pacific ridge moved into the area. On September 2 fire danger was high at all stations as the next Pacific front moved through the region.

The flow aloft became zonal from the Gulf of Alaska eastward, and the short-wave trough associated with the next Pacific front was imbedded in the flow.

Still another extension of the Pacific High began to move into the northern part of the region behind the front September 3. Although most stations had fire load indexes of 20 or less on that day, Kalispell still reported 42 in the strong gradient area behind the cold front.

Prediction.--In anticipating the Pacific High type in this region the upper-air pattern should be studied. This pattern must be one that has a trough off the West Coast and a ridge over the Rockies, or a flow that will develop into this pattern. At the surface, a strong ridge must be building over the eastern Pacific and into the western part of Canada. As soon as the ridge begins to break off over British Columbia, it should be expected to move southeastward down along the Divide or to the east of the Divide. In a study of all the cases a few were noted in early spring or late fall which had the upper trough over the Rockies and the ridge at about 150°W. The movement southeastward of the surface High was the same as under the more common ridge location. Fire danger was not nearly as high because cooler air was brought into the region from the northwest.

Table 39 provides some average values of several weather elements and fire load indexes that may be of value as forecasting guides.

The breakdown of this type comes with a strong upper-air impulse of cooler air moving through from the Pacific. This is usually preceded by a rapidly falling height field aloft along the West Coast. If there is a closed Low in the offshore upper trough, an indication of its movement out of the trough may be obtained by the use of Henry's rule 7/. This rule states that a cut-off Low will move out of the trough when a 24-hour height-fall center approaches from the northwest to within 1,200 nautical miles of the Low. After the cut-off Low moves out of the trough, the upper trough weakens, the flow goes into a more zonal pattern, and the fire danger decreases.

This method of breakdown is usually accompanied by considerable precipitation. If the breakdown of this type is accompanied by only a weak short-wave trough moving out of the Pacific trough and across the Pacific Northwest, some light shower activity and possible thunderstorms can be expected. In about 50 percent of the cases fire danger is lowered in this fashion. On the other hand, if no showers occur, the fire danger may remain unchanged or even peak in the strong, shifting winds accompanying the trough passage. As has been previously mentioned the area to the east of the Cascade Mountains in Washington and Oregon is occasionally affected by such trough passages and the high fire danger persists as long as winds remain strong.

7/ Unpublished Master's Thesis on file at University of Chicago

Table 39.--Averages of weather elements and fire load indexes, in the southwest quadrant of the Pacific High for high fire danger days during July and August, Northern Rockies and Northern Intermountain region

Upper-air pattern	Temperature	Relative Humidity	Prevailing direction	Wind speed	Fire load index
	°F.	Percent		Mph	
Moderate meridional ridge	85-95	8-12	Southwesterly	10-20	35-40
Strong meridional ridge	95-105	5-10	Southerly	10-20	1/ 50-70

1/ Peaks to 99.

The Northwest Canadian High Type

One percent of the cases of high fire danger during the 10-year period was from the Northwest Canadian High type. These were observed in the spring, through June, and in the fall. The case selected to illustrate this type is the period of June 8-11, 1955 (fig. 63).

June 8 a meridional ridge aloft was over the western part of the United States and Canada. At the surface a long ridge of high pressure was nosing down into the country across British Columbia and Alberta along and to the east of the Divide. By June 10, the meridional ridge had narrowed, and a center was located over the Divide of southern British Columbia and southern Alberta. The component in the upper-air flow was out of the southeast over Idaho and Washington. By this time another surface ridge from the Pacific had pushed northeastward, with the leading edge moving into western Washington and western Oregon. The center of the Northwest Canadian High was over the area to the east of the Divide in the United States and Canada. The circulation at the surface over the region was out of the southeast as a result of the combined pressure gradients both at the surface and aloft. Between the High to the east of the Divide and another High to the west of Washington and Oregon, a long surface trough developed across the western part of the region. Warm dry conditions with rather strong southeasterly winds developed, possibly aided by subsidence in the ridge aloft. June 10, the fire load index at Boise was 42; at Yakima, 40; and at Redmond, 29. This condition was alleviated June 11 as the winds in the upper ridge dropped off to low values of 10 knots or less, and the pressure gradient at the surface relaxed as the High moved off slightly to the east.

Prediction.--This type develops under the influence of a strong meridional ridge aloft over the western part of the United States and western Canada. At the same time, a strong High at the surface in northwestern Canada begins to move southward out of the Yukon down across British Columbia. If the upper ridge forms a closed center over British Columbia, the easterly component of circulation aloft may be strong enough around the south side of the closed center to influence the easterly flow at the surface in this region. As soon as this upper circulation pattern relaxes, the strong support at the surface is lost and the southeasterly flow at the surface subsides. On some occasions the upper-air support takes the form of a ridge over the area to the west of the Divide; the flow in a deep trough carries the air strongly across the Divide from the northeast. This pattern has the effect of creating chinook conditions on the west side of the Divide in the Upper Snake River Drainage, provided the surface pressure pattern is suitable.

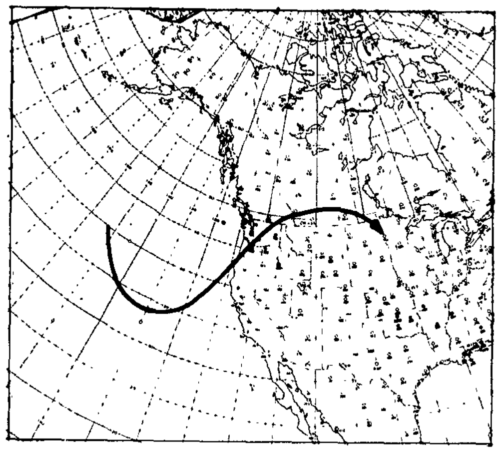


Figure 61. --Plot of 500 mb ridge and trough positions for the Pacific High type with meridional ridge.

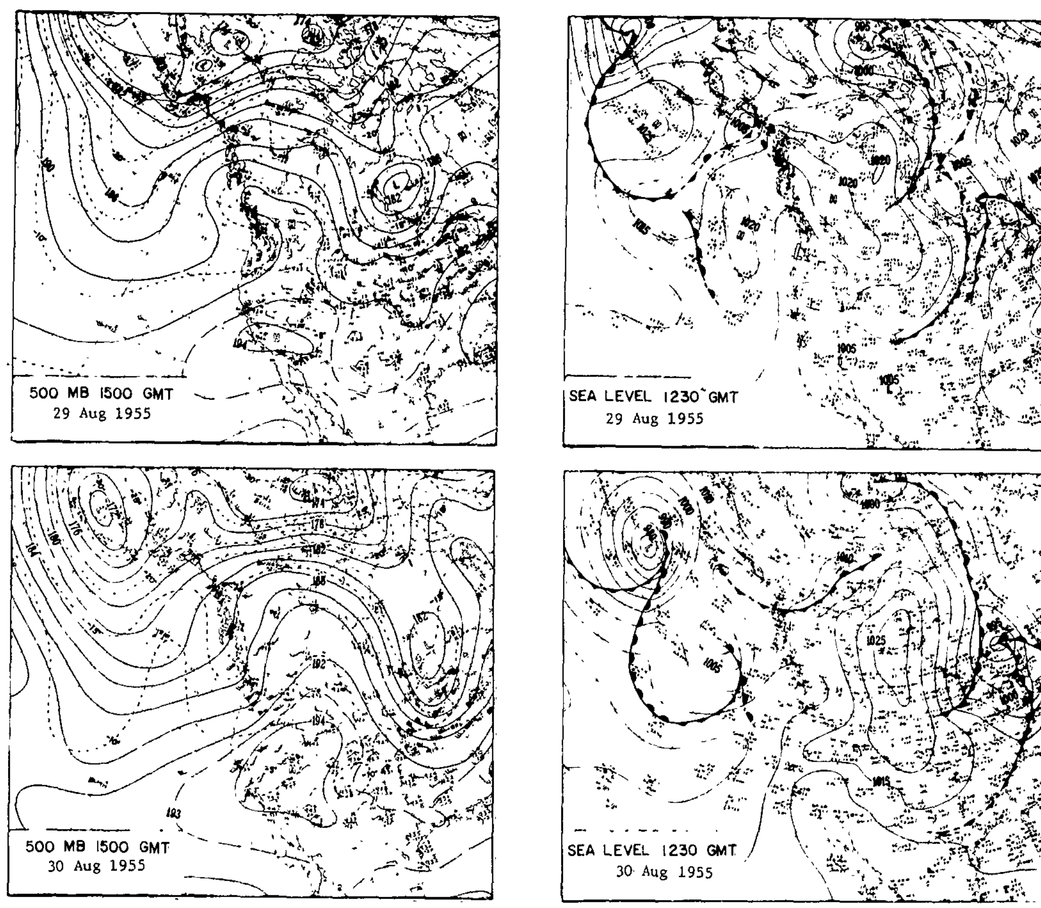


Figure 62. - Surface and 500 mb charts, August 29-September 3, 1955.

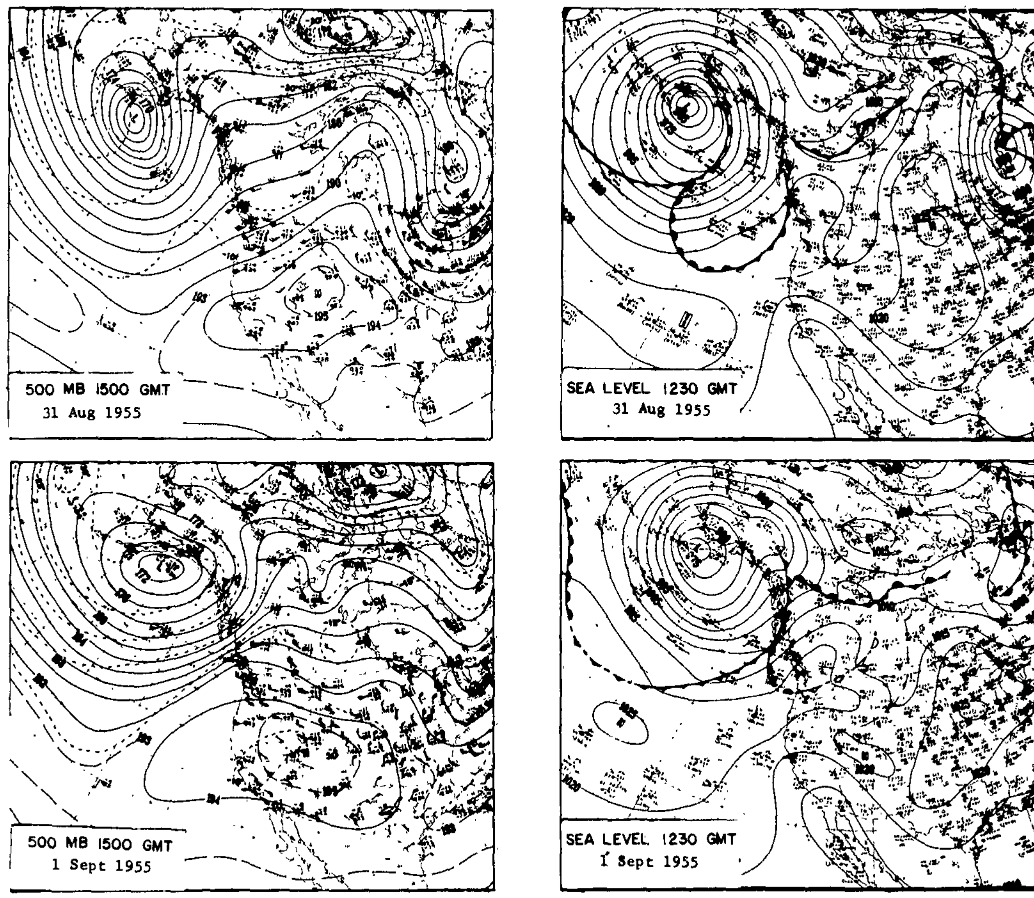


Figure 62. --Continued.

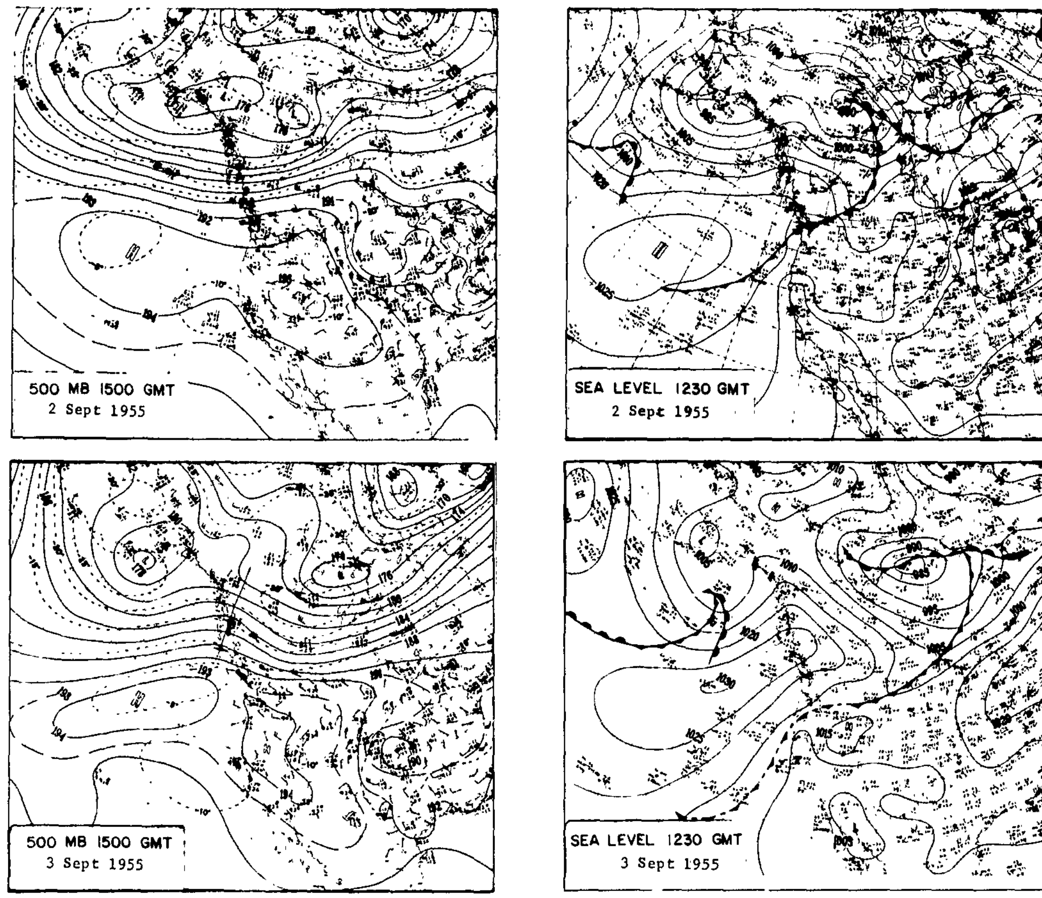


Figure 62. --Continued.

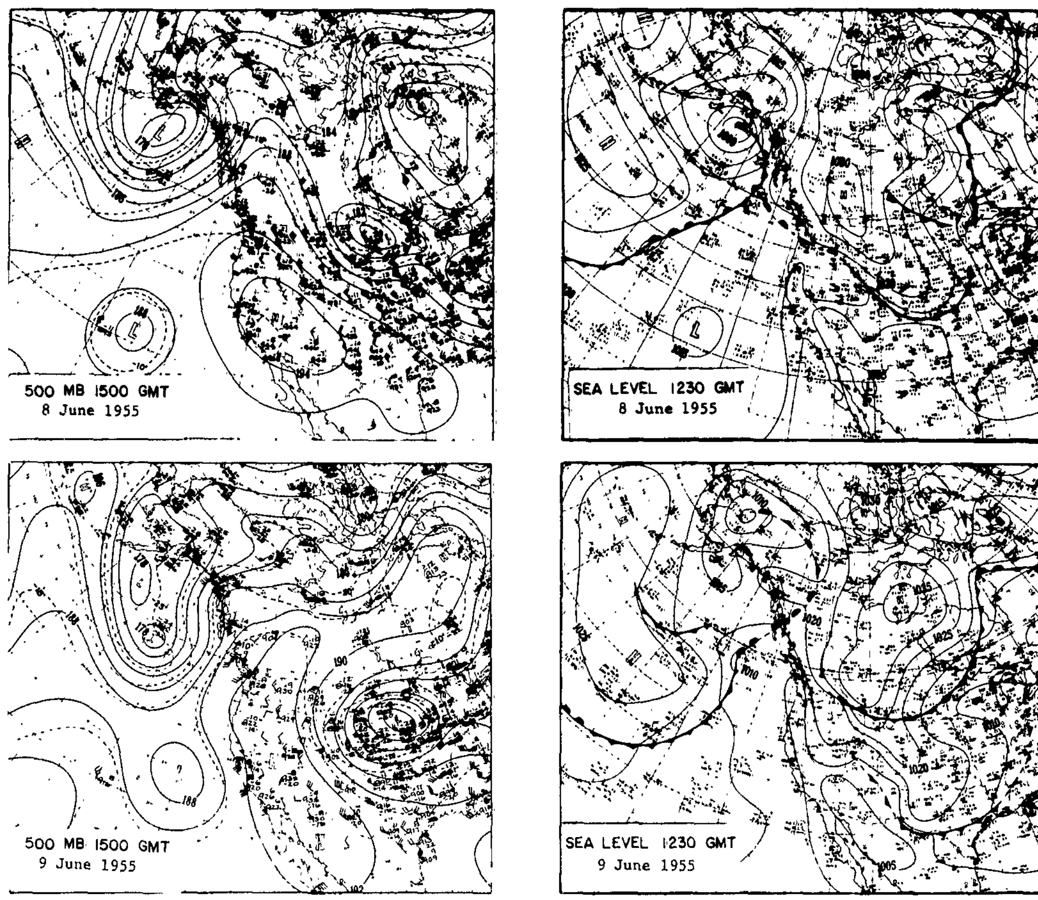


Figure 63. --Surface and 500 mb charts, June 8-11, 1955.

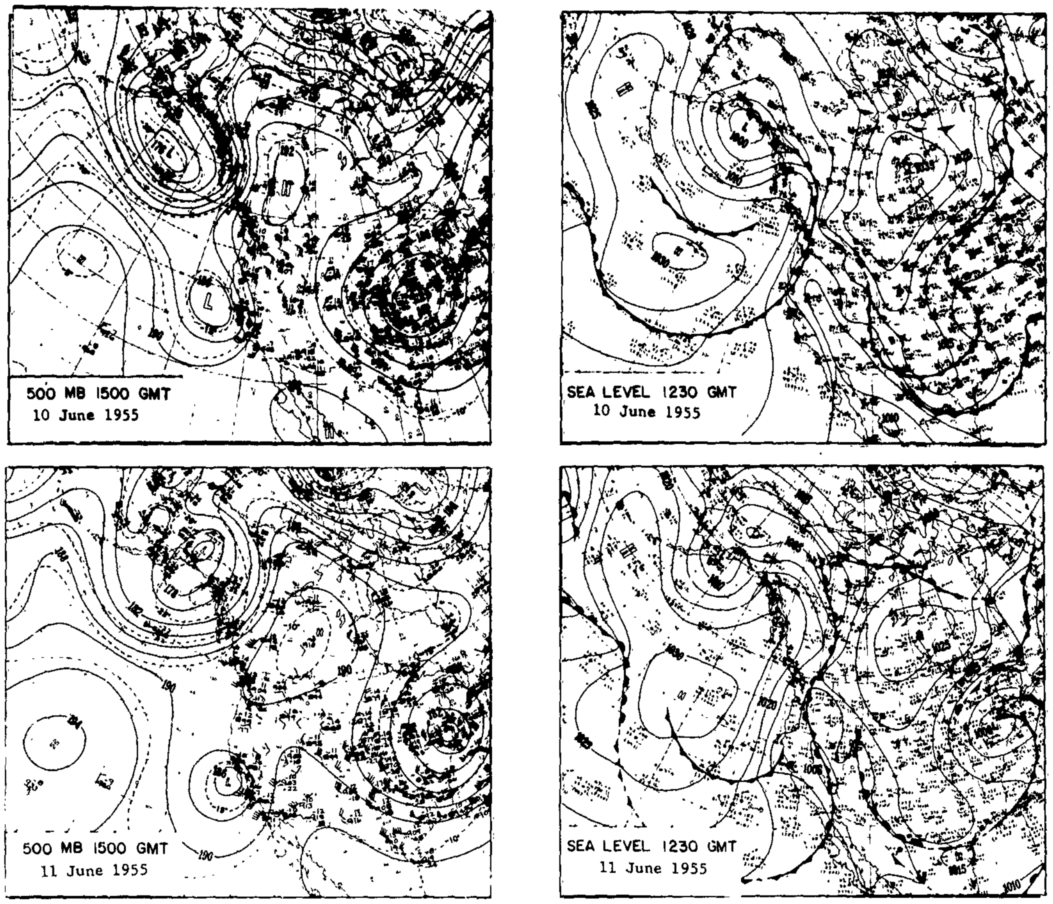
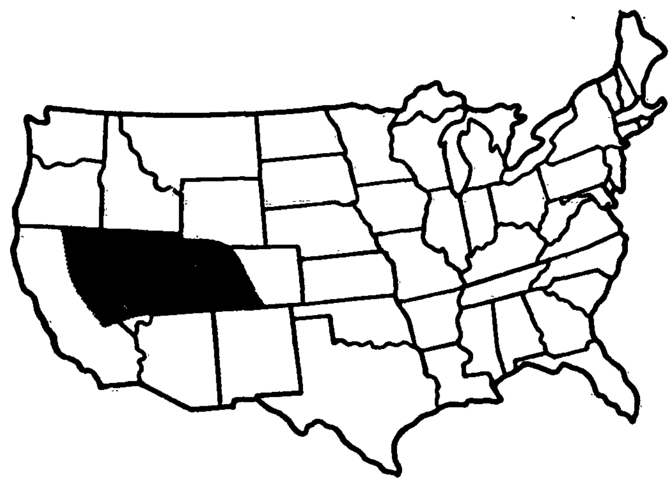


Figure 63. --Continued.



Central Intermountain Region

The Central Intermountain region includes the states of Nevada (except the extreme southern portion), Utah, and Colorado from the Rocky Mountains westward. Elevations of the lower valleys in the region are between 4,000 and 5,500 feet above sea level and the elevations of most mountain ranges are between 8,000 and 13,000 feet. Mountains and valleys are generally oriented north-south. The important exception is the Uinta Range of northeastern Utah, which is one of the few major east-west mountain ranges in the country.

The mountainous terrain is generally rough and disjointed, and the continuity of natural fuels is often poor, thus providing a certain amount of natural protection against fire spread under moderate wind conditions. Natural fuels in the valleys are primarily light fuels, grasses, and scrub brush. The heavier fuels are located at higher elevations, generally above 6,000 feet. Major population centers are located in valleys and generally below 5,500 feet elevation.

The season of high fire danger in the Central Intermountain region normally extends from mid-May until mid-October. However, short periods of high fi-e danger and some wildland fires have occurred as early as mid-March and as late as mid-November. The area of maximum fire occurrence, as well as highest fire load index, seems to move northward during the spring from the Southwest region into the central and northern portions of the Intermountain region, and retreat southward in the fall. Thus, while the Southwest has a season with two fire danger maxima, spring and fall, the Central Intermountain region has a single season centered around mid-summer (table 40).

Table 40.--The seventy-fifth percentile of fire load index, by stations and months, Central Intermountain region, 1951-60

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Fire load index											
Reno	2	5	10	15	16	24	31	31	26	13	6	3
Winnemucca	2	3	10	17	20	29	43	47	33	20	8	3
Salt Lake City	1	2	5	8	13	26	33	31	29	15	5	1
Cedar City	3	3	12	21	31	56	45	37	37	25	11	5
Grand Junction	2	3	10	18	29	52	40	35	31	15	6	3
Eagle	1	1	3	11	16	29	24	16	20	12	3	1

Table 41.--Number of days with fire load index 37 and above, by station, Central Intermountain region, 1951-60

Year	Reno		Winnemucca		Grand Junction		Salt Lake City		Cedar City		Eagle	
	Fire load index equal to or greater than--											
	37	50	37	50	37	50	37	50	37	50	37	50
1951	9	3	33	8	41	21	9	2	58	34	31	13
1952	10	2	19	6	26	10	22	8	35	22	15	6
1953	20	6	35	9	44	28	35	20	49	28	12	4
1954	48	19	68	34	33	21	21	11	54	28	8	1
1955	39	19	50	25	45	24	23	10	52	31	21	7
1956	16	5	40	13	82	50	56	25	78	39	16	5
1957	26	12	41	15	6	2	30	13	22	7	2	1
1958	6	1	30	14	48	28	35	26	48	28	23	16
1959	10	3	56	29	74	34	15	6	56	36	3	0
1960	16	6	65	36	84	42	34	20	76	46	6	1
Total	200	76	437	189	483	260	271	141	470	299	137	54

About 75 percent of all class E fires (300 acres and larger) occurred during July, August, and September; most of the rest occurred in June and October. The grasses and other light fuels at lower elevations are susceptible to rapid fire spread early in the season, during late May, June, and early July, while the heavier fuels at higher elevations are still wet, snow-covered, or both. The heavier fuels are most susceptible during mid-summer and late summer and early fall.

During late fall, winter, and early spring (November through March) periods of high fire danger are rare. The first general snow storm of the fall which will allow snow to remain even at lower elevations usually occurs in early November. From that time until early April the ground is generally wet or snow-covered. The winter snow pack at higher elevations, above 8,000 feet, usually remains until late May or early June. In addition, the synoptic weather patterns which bring severe burning conditions to the region during the summer months are accompanied by precipitation, low temperatures, and higher humdities when they occur during the cold season.

The weather stations used to represent the Central Intermountain region were Reno and Winnemucca, Nevada; Salt Lake City and Cedar City, Utah; and Grand Junction and Eagle, Colorado. The normal level of fire load index is relatively high at these stations (table 41).

Because of the large number of days of high fire danger, it was not possible to investigate the weather maps for each case. Then, too, in mountainous, rugged terrain such as this, local effects will occasionally produce quite severe burning conditions under a generally mild situation. Conversely, local areas may occasionally show low fire danger during a generally severe condition due to smaller scale terrain effects and moisture sources. To make a selection of cases, all periods of two days or more with fire load index of 22 or higher were plotted on scratch charts for each weather station in the area together with all C, D, and E National Forest fires for the 10-year study period. From the scratch charts, periods were selected when an extended period of high fire danger occurred over a major portion of the region. Forty such extended periods, ranging in length from 3 to 26 days, were selected for study. Often a period of high fire danger was caused by several synoptic patterns which followed one another without a break in the period. The average length of time that a specific pattern dominated the area during a period of high fire danger was 6.8 days.

The below-normal relative humidity and above-normal wind necessary to produce unusually high fire load index in this semi-arid region are associated with three general upper-air flow patterns. The first two are highly meridional or blocking patterns and the third is basically a zonal flow pattern. Generally a combination of surface winds stronger than 15 mph and afternoon relative humidity less than about 18 percent are necessary to produce periods of high fire danger in this region.

A lengthy preliminary period without precipitation does not seem to be important since the light fuels dry rapidly during the warm months and the heavier fuels become progressively drier as the summer advances.

The major source of dry air during the season of high fire danger is subsiding Pacific air masses which move around the north and east side of the Pacific high pressure cell and then into the western United States. They pick up very little moisture over the relatively cool ocean waters. The major sources of continuous strong wind are strong southerly pressure gradients aloft and strong surface pressure gradients associated with frontal systems.

Meridional Ridge - Southwest Flow Pattern

Two sub-patterns in the meridional ridge category are sufficiently different to warrant discussion separately. The first pattern is one in which a trough is found along the West Coast. The second, which frequently is a further development of the first, has a cut-off Low in the Pacific Coast trough.

A composite 500 mb chart of the cases in the first sub-pattern (fig. 64) shows these important features: (a) a Low centered in extreme southeast Gulf of Alaska, most often just off Vancouver Island with a well-developed trough extending southward just off the Pacific Coast, (b) a small anticyclone over Arizona and New Mexico with a ridge to the north-northeast, and (c) a strong ridge extending from the Pacific anticyclone into central Alaska. Surface air entering the Central Intermountain region comes by way of southern California and is warm and dry. The high-level anticyclone over the Southwest plays two important roles: (a) it maintains a strong southerly gradient over the Central Intermountain region, and (b) it effectively blocks entry of moist Gulf of Mexico air into the region.

At the surface, minor low pressure systems move eastward out of the West Coast trough, along or just to the north of the Canadian border. Trailing dry cold fronts from these centers often become stationary east-west across or just to the north of the region, maintaining strong surface pressure gradients. High fire danger may occur in the pre-frontal, or occasionally the post-frontal area.

This pattern usually develops as a weak anticyclone aloft, enters the Pacific Northwest coast and moves fairly rapidly southeastward across the region. The dry air associated with this High sets the stage for severe conditions. The following trough stalls along the West Coast and deepens southward as the Pacific high pressure cell builds a strong ridge northward or even a block over Alaska. Another common mode of formation is the deepening and stagnation of minor upper troughs as they move southeastward to the Pacific coast around the Alaskan ridge.

Breakdown of this pattern normally occurs in one or a combination of two ways. First, the High aloft over Arizona or New Mexico may move eastward, thus relaxing the gradient and allowing moist air from the Gulf of Mexico to enter the region. Second, the trough along the Pacific Coast may move eastward into the region accompanied by moisture and lowering temperatures.

This pattern occurs more frequently than any other and tends to persist for the greatest length of time. Periods of severe burning conditions often last from 5 to 8 days, a few as long as 2 weeks. Surface weather conditions include southerly afternoon winds of 15 to 25 mph and afternoon relative humidities of 10 to 20 percent. Although this pattern may produce severe burning conditions from April to November, it occurs most frequently during mid-summer. Sixty percent of all cases studied occurred in June, July, and August.

The maps for September 4-12, 1952, show the formation and breakdown of this sub-pattern (fig. 65). During the early stages, an upper-level High moved into and dominated the Southwest as a Pacific trough extended southward along the coast. A series of short waves aloft moved rapidly eastward along and just north of the Canadian border, while the associated surface frontal systems remained north of the Central Intermountain region. Breakdown occurred in this case as a cut-off Low (second sub-pattern) formed September 10 and moved eastward into the region. Showers and low temperatures advanced eastward across the region, and breakdown was complete by September 12.

The second sub-pattern (fig. 66) in which a cut-off Low develops in the Pacific Coast trough, is essentially a further development of the preceding one. Thus, the remarks concerning the development of the preceding pattern also generally apply to this pattern. Very often the cut-off Low develops simultaneously as a blocking High builds into the Gulf of Alaska or even into the Yukon. At such times, the digging of relatively cool air on the back side of the Pacific Coast trough is an important factor. Although the cut-off Low pattern is usually associated with Gulf of Alaska or western Canadian blocks, this is not always the case. In a fairly large number of cases, only a strong ridge had developed into the Yukon or eastern Alaska. The Pacific high cell and its northward extension, as well as the High center in the Southwest (fig. 66) have a mean location about 7 degrees longitude further east than in the first sub-pattern (fig. 64).

As the cut-off Low forms near the Pacific Coast of California or southern Oregon, a very strong pressure gradient develops over the Central Intermountain region. At the surface, a low pressure center is most often located along or just inside the Pacific Coast, and a strong southerly surface flow is found over the Intermountain region. Occasionally both the surface and upper-air patterns may shift far enough eastward to allow showers and cold air to invade western Nevada, while the balance of the region continues to experience warm dry southerly winds.

Breakdown of this pattern normally occurs in one of two ways: (a) The cut-off Low drifts eastward into the region, accompanied by lowering temperatures, precipitation, and higher relative humidities; (b) The cut-off Low retrogrades westward into the Pacific, or even occasionally moves northward, and thus relaxes the gradient. Occasionally when the Low retrogrades, increased moisture from the Gulf of Mexico may reach the region, around the bottom side of the High over the Southwest.

The most severe fire weather is produced by this pattern. The unusually strong, hot, dry flow from the south will often produce afternoon surface wind in excess of 30 mph and relative humidities between 5 and 15 percent. Although this pattern is very persistent, often lasting up to 2 weeks, the periods of unusually severe fire weather are normally considerably shorter, ranging from 2 to 5 days. The almost random movement of the cut-off Low causes considerable variability in the surface wind velocities involved. The pattern may produce periods of high fire danger from April to November, with most frequent occurrences during mid-summer. Roughly 50 percent of the cases studied occurred during July and August.

The maps for June 7-15, 1953 (fig. 67) show the development and breakdown of the second sub-pattern. As the blocking High formed over western Canada and shifted southward in this case, the Low off the Pacific Northwest coast, which represented the lower lobe of this blocking situation, became well defined as a cut-off Low and shifted southward to the northern coast of California. At the same time, the upper-level High originally over the southeastern United States shifted westward, thus intensifying the gradient. By June 9 a very strong south-southwesterly flow aloft occurred over the Central Intermountain region. Apparently the transport of momentum downward in this warm, dry upper flow produces the strong surface wind which, together with high temperature and low relative humidity, is typical of this pattern. Surface fronts are rare with this pattern except those associated with the upper-level Low near the coast, and these will normally be found over central California or extreme western Nevada.

Breakdown in this case occurred on June 13 as the Pacific Coast Low receded northward and the gradient relaxed.

About the first indication that a Meridional Ridge--Southwest Flow pattern will develop is the northward extension of the Pacific ridge aloft. In fact, there appears to be a positive correlation between the amount of northward extension of this Pacific ridge and the severity of the fire weather in the Central Intermountain region. In this pattern, the air mass involved has a subsiding trajectory around the top side of the Pacific ridge and picks up very little moisture over the relatively cool Pacific water.

In the breakdown of these systems during the summer and fall months, occasionally the period ended because of the advection of very moist air into the system from hurricanes which formed off the coast of Mexico.

Pacific High Type - Meridional Flow

The Pacific High type with meridional flow may be considered a combination surface synoptic weather type and upper-air pattern. In the southwest flow patterns discussed above, the surface pressure distribution is troughy, and frontal systems tend to become stationary or remain north of the area. However, in this type there are definite frontal passages followed by Pacific Highs. The meridional flow aloft is from the northwest which is conducive to steering breakoffs from the Pacific high pressure cell through the region.

A composite 500 mb chart for the cases in this type (fig. 68) shows these important features: (a) the Pacific ridge displaced to the east of normal and extending well into the eastern Gulf of Alaska and Yukon, sometimes forming a blocking High over the Yukon; (b) an upper-level Low over south-central Canada, with a trough extending southward in mid-United States; (c) a small High centered over Arizona or southeastern California; and (d) short-wave troughs moving southward from western Canada into the western United States in the northwesterly upper flow.

The upper-level ridge in the eastern Gulf of Alaska is maintained by warm advection on its west side from a mean trough over the Aleutians. Short-wave troughs moving southward out of western Canada into the western United States are accompanied at the surface by dry cold fronts that move through the area from the northwest and cause a strong surface flow of dry air. Periods of high fire danger during this type may be said to be "recurring or intermittent" as each new surge brings its period of strong shifting winds and low humidities. Afternoon winds of 15 to 30 relative humidities generally below 15 percent may be expected with this situation.

Breakdown of the northwesterly flow pattern occurs when the central Canadian upper-level Low shifts far enough eastward to allow the Pacific upper ridge to move directly over the Central Intermountain region, thus relaxing the gradient. Occasionally a stronger short-wave trough over western Canada will move southward over the Intermountain region and bring in moist air. Another common cause of breakdown is the retrogression westward of the Pacific Coast ridge or block which relaxes the gradient.

This Pacific High type is important for two reasons. First, unusually dry air is produced at the surface from the subsidence around the east side of the Pacific ridge. Second, northwesterly flow patterns are often preliminary to the development of a southerly flow type--as the Gulf of Alaska Low drops southeast to the Pacific coast and stagnates.

Periods of high fire danger resulting from this flow pattern occur most often during the mid-summer; 70 percent of the cases studied occurred in July, August, and September. The periods were generally 3 to 5 days in length although they occasionally extended intermittently up to 12 days.

In general the Pacific High type which is associated with northwesterly flow aloft tends to occur less often and produce shorter and less severe periods of high fire danger than the southwest flow pattern. The location of a mean upper trough over mid-continent and a mean ridge near the Pacific Coast is in direct contrast to the normal summer tendency toward ridging aloft over mid-continent and troughing off the Pacific Coast. Thus, such Highs as do enter the Pacific Northwest are associated with progressive or occasionally retrogressive patterns which tend to reestablish the norm. This pattern does play an important part in the scheme of things, however, since it is often associated with very dry air, producing relative humidities sometimes as low as 4 to 8 percent. Extended periods of severe burning conditions often result when the northwesterly flow pattern moves on, leaving dry fuels and dry air over the region, and then is followed by one of the more severe southwesterly flow patterns.

The period September 10-16, 1951, illustrates the Pacific High type with northwesterly flow aloft (fig. 69). The Pacific ridge built northward into the Gulf of Alaska and moved to the eastern Gulf September 10 and 11 as a mean upper-level trough was established in central Canada. September 11 and again September 14 and 15, short-wave troughs moved southeastward in the northwesterly flow. Each was accompanied by a surface frontal system which in turn was followed by a Pacific High. Fire danger peaked with the strong winds associated with these systems. The fire danger decreased as the upper-level ridge moved over the western states September 16. The relief was only temporary, however, as the upper-level ridge was later re-established off the West Coast and the type repeated.

Pacific High Type - Zonal Flow

Pacific Highs following cold fronts also pass through the Central Intermountain region with a zonal pattern aloft. The pattern aloft is characterized by fairly rapidly moving waves of small amplitude advancing eastward in a band of westerlies which is strong and generally displaced a little to the north of the normal position. The pattern often develops as the result of blocking action in the western Pacific or near the Asiatic coast. The resulting downstream confluence and its attendant strong thermal gradient cause a zone of fast westerlies in the eastern Pacific and across western North America. At the surface, rather weak low pressure centers move rapidly eastward across southern Canada with trailing dry cold fronts extending southward into the Central Intermountain region, each followed by a rapidly-moving Pacific High.

High fire danger occurs in the dry air and strong surface pressure gradients associated with the frontal passages. Since the frontal systems are moving rapidly, the periods of high fire danger are intermittent, but are generally quite severe. Relative humidities less than 20 percent and winds of 15 to 30 mph are the rule.

Breakdown of the pattern aloft most often occurs as the zonal westerlies buckle into a more meridional, large-amplitude flow pattern. When this happens the type may develop into one of the meridional severe fire weather patterns discussed above. Occasionally a deep upper trough forms over the region and is accompanied by precipitation and lowering temperatures. At other times the troughing may occur in the eastern Pacific, and a strong ridge with light variable winds will develop over the Central Intermountain region. Dissipation may also occur with a breakdown of the western Pacific block, which results in a relaxation of the zone of confluence and a weakening of the westerlies over western North America.

The Pacific High type with zonal flow tends to occur most frequently during the spring and fall months and has a minimum in July. The average length of the periods under this type, each caused by the passage of several frontal systems, is generally 4 to 7 days, although a few cases lasted from 11 to 13 days.

Maps for September 17-23, 1958, illustrate this type (fig. 70). During this period three separate frontal systems, each followed by a break-off of the Pacific high pressure cell, passed through the region--on September 17, 19, and 22. Breakdown of the zonal pattern aloft began September 23 as the third short-wave trough deepened over the region.

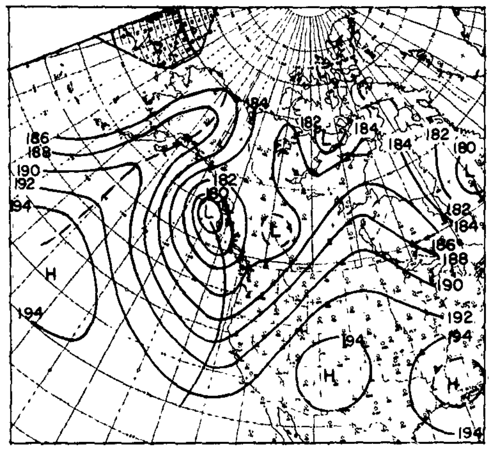
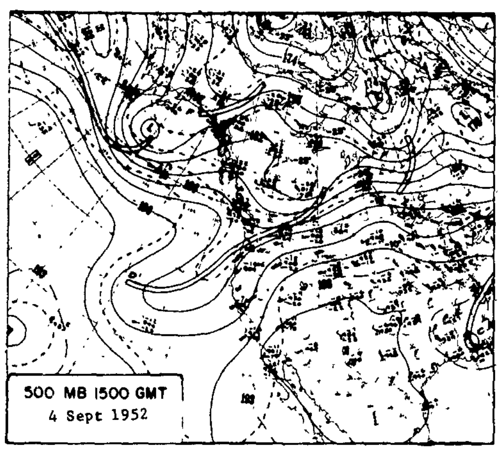
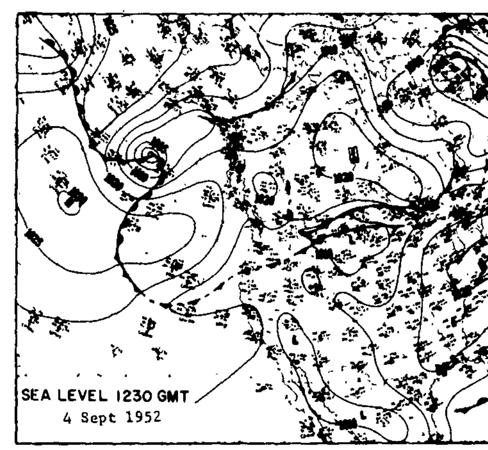
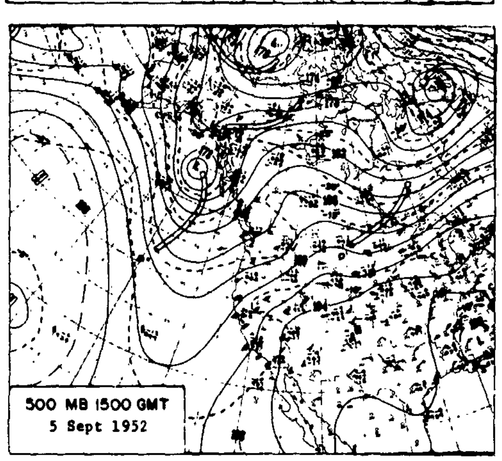


Figure 64. --Composite 500 mb chart for Meridional Ridge - Southwest Flow cases in which trough, rather than cut-off Low existed along the Pacific Coast.







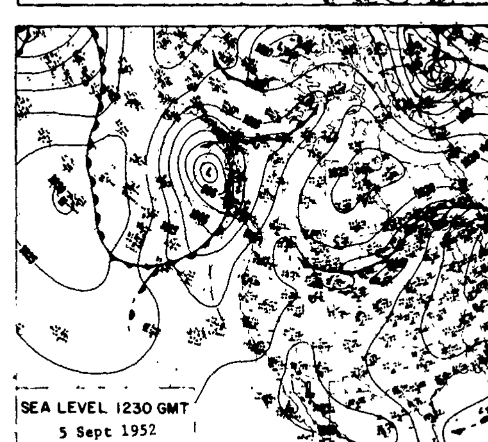


Figure 65. --Surface and 500 mb charts, September 4-12, 1952.

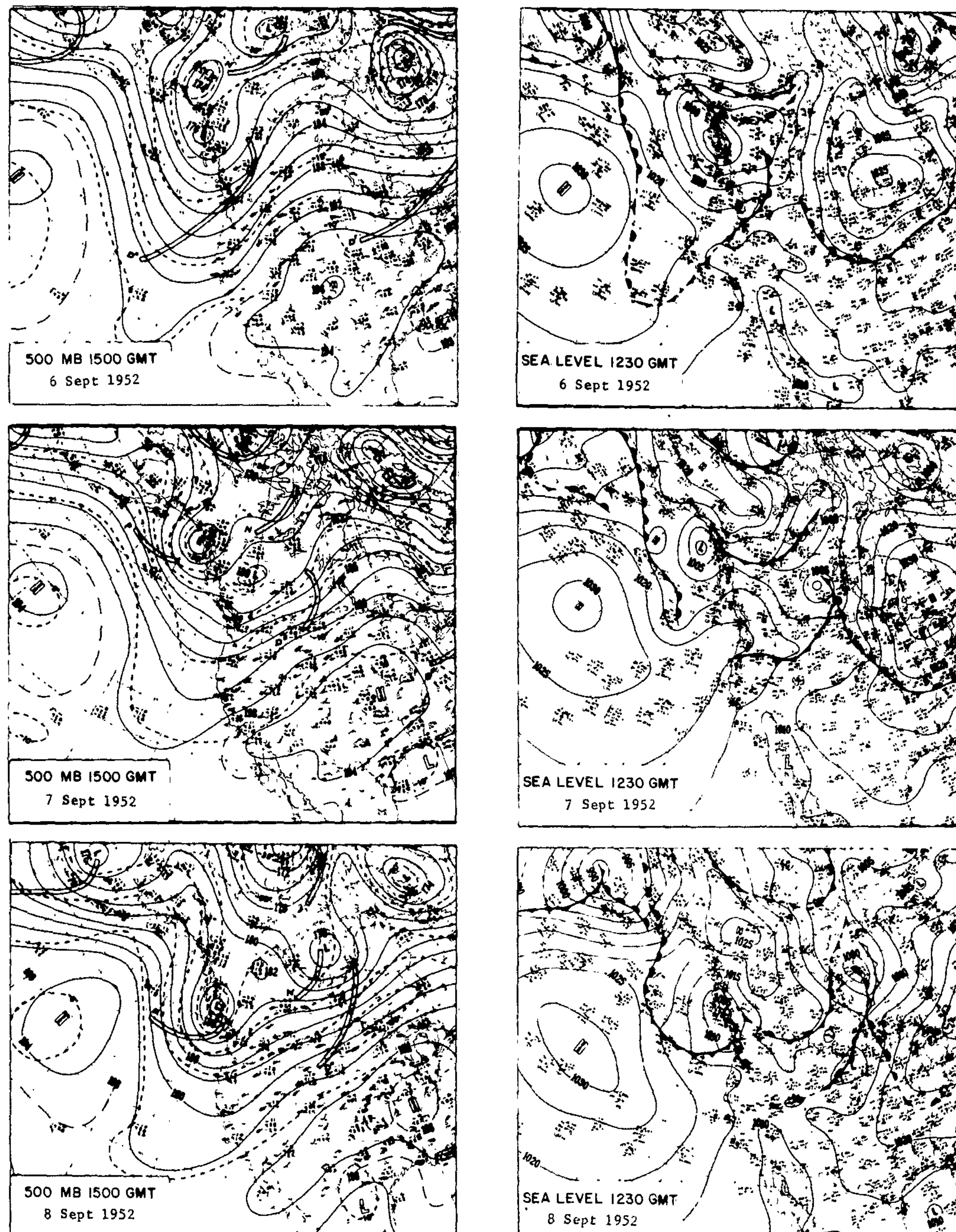
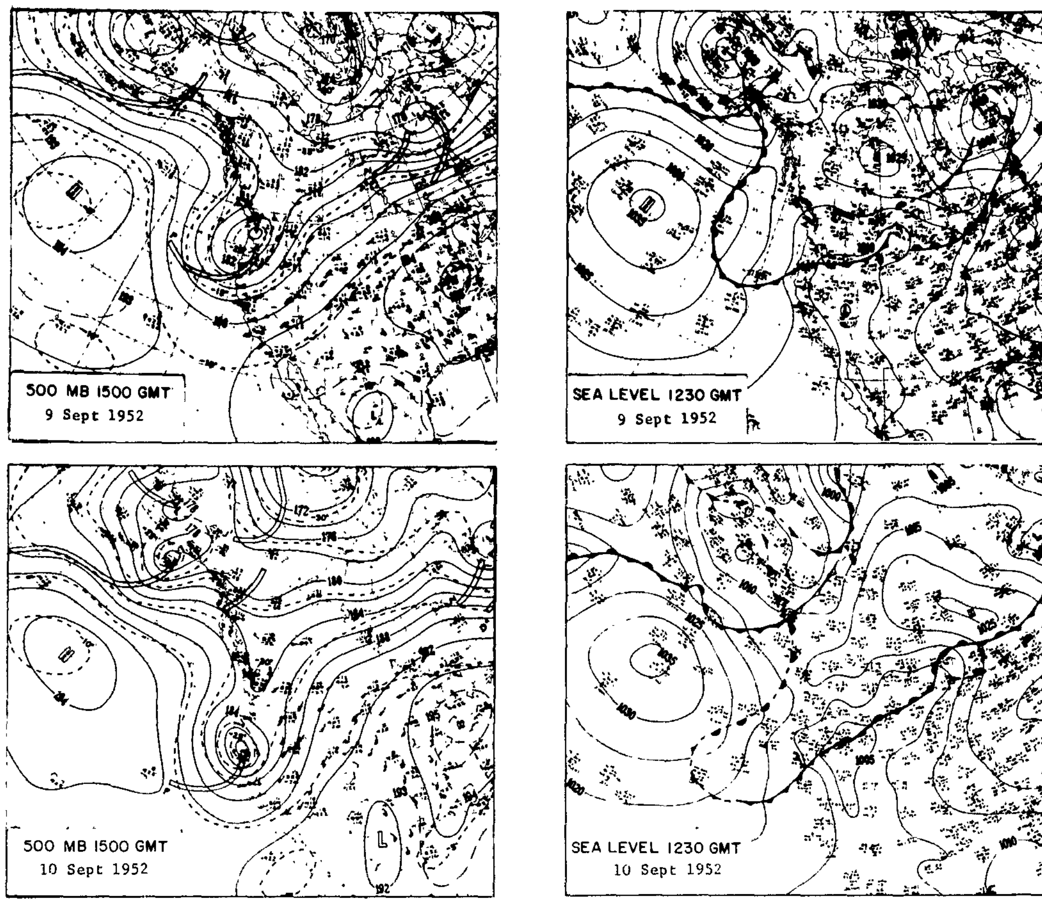


Figure 65. --Continued.



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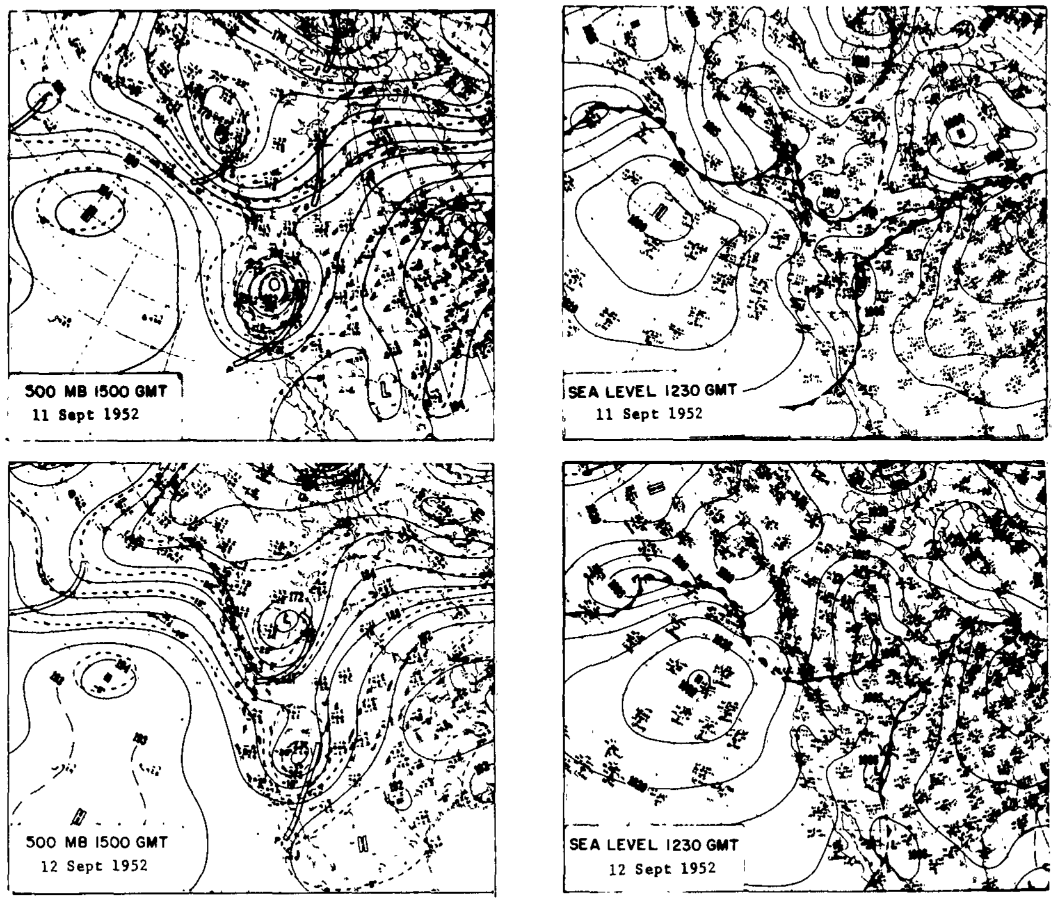


Figure 65. --Continued.

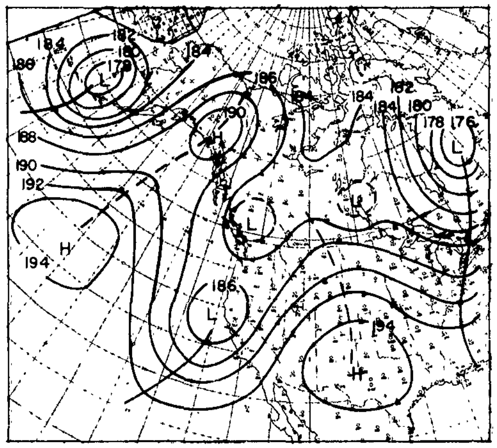


Figure 66. --Composite 500 mb chart for Meridional Ridge - Southwest Flow cases in which a cut-off Low is found along the Pacific Coast.

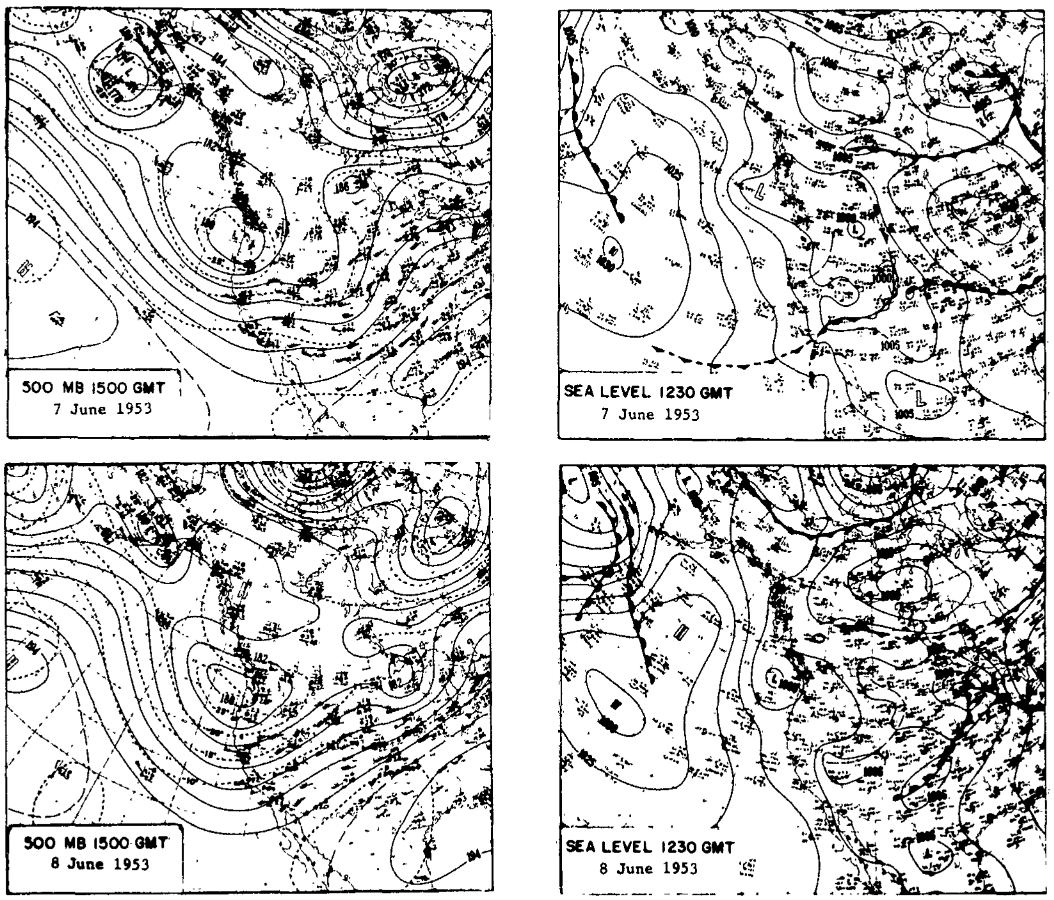


Figure 67. --Surface and 500 mb charts, June 7-15, 1953.

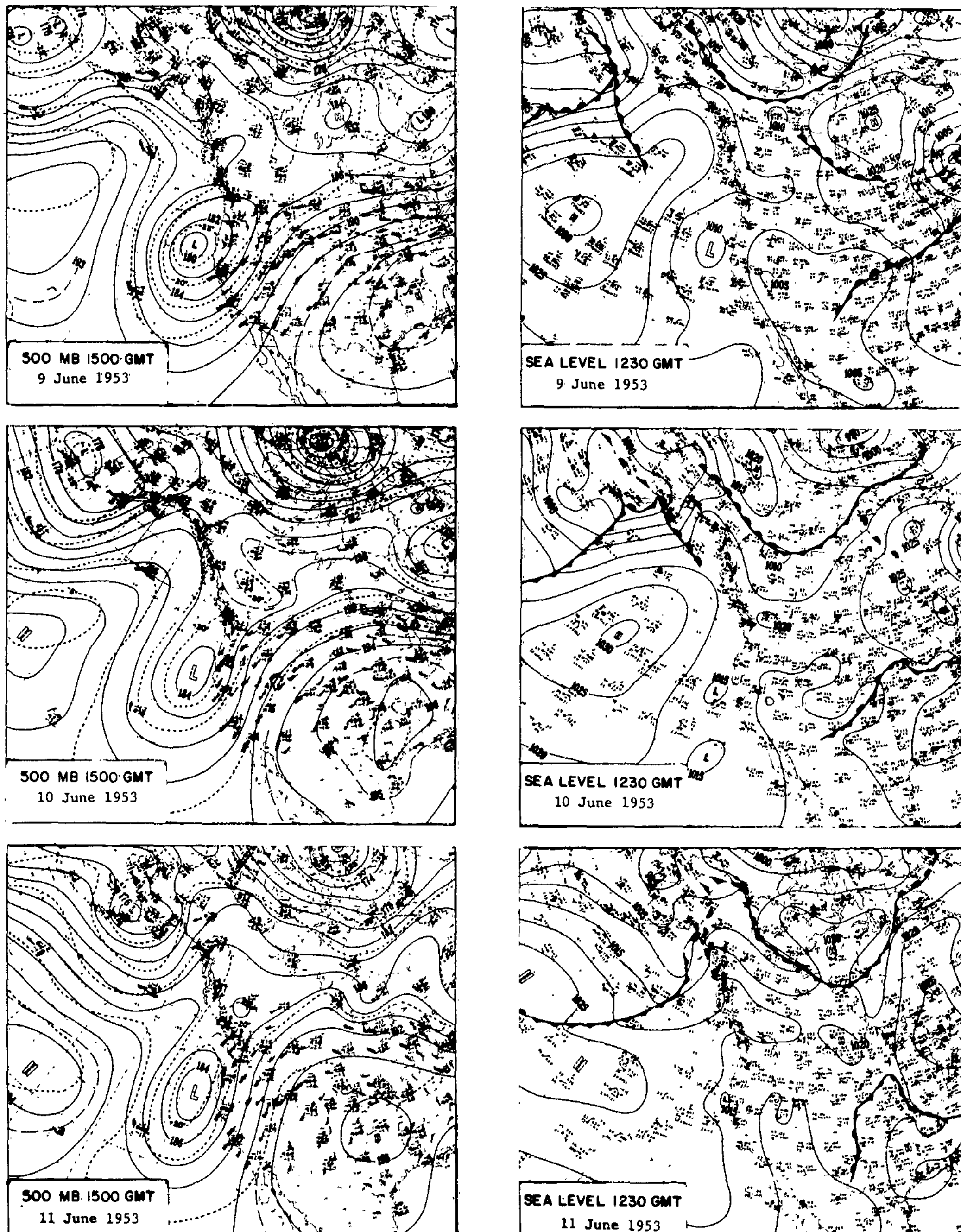


Figure 67. --Continued.

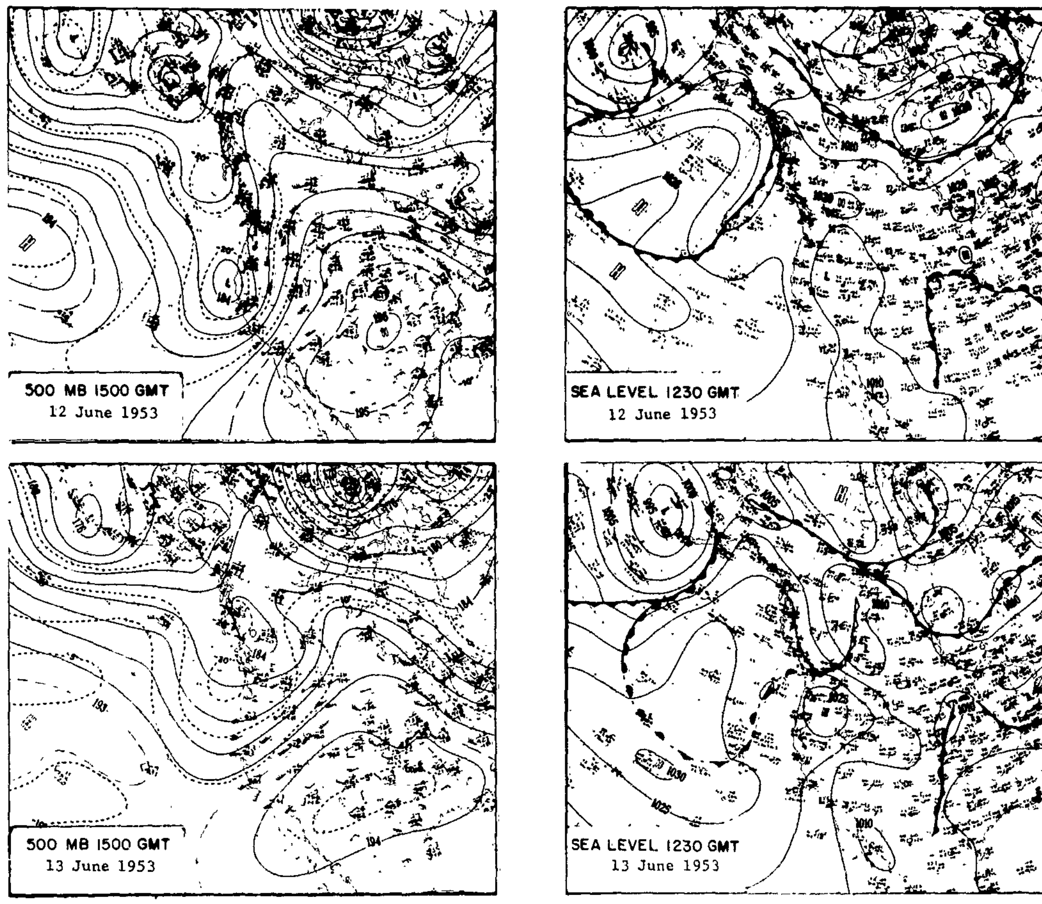


Figure 67.--Continued.

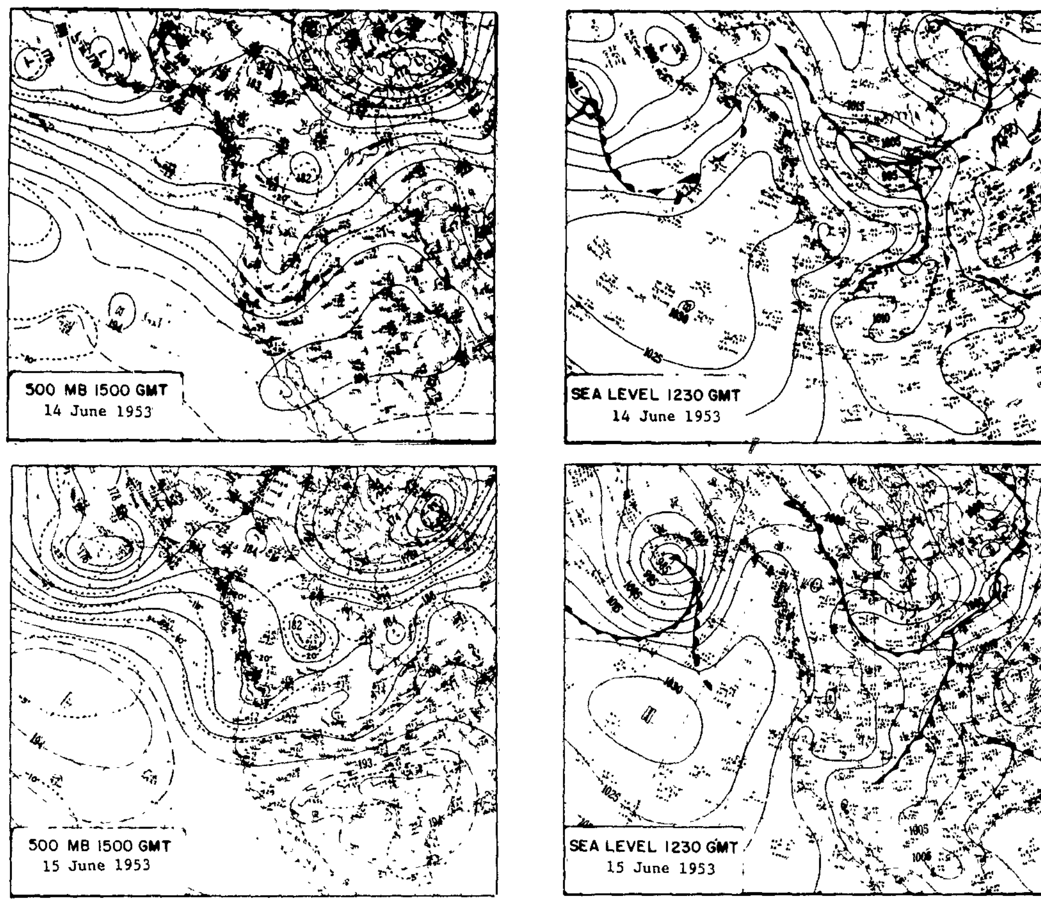


Figure 67. --Continued.

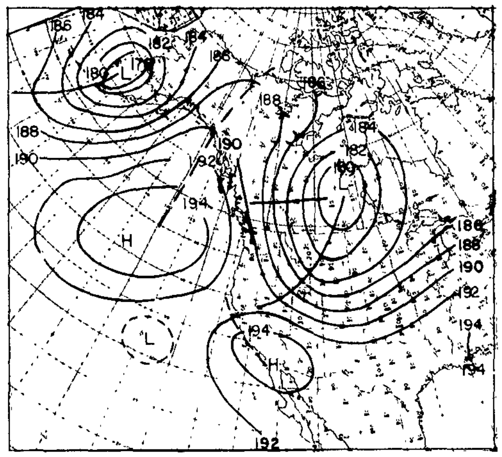


Figure 68. --Composite 500 mb chart for Pacific High cases with meridional flow aloft.

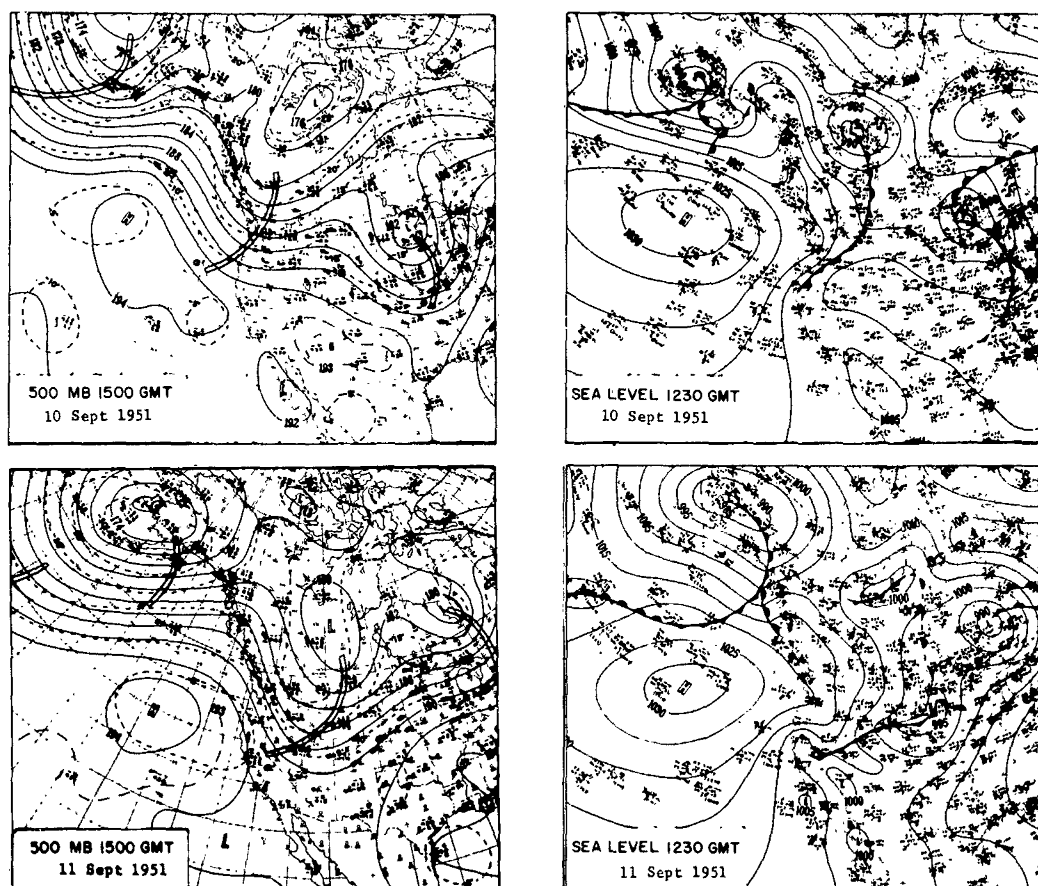


Figure 69. --Surface and 500 mb charts, September 10-16, 1951.

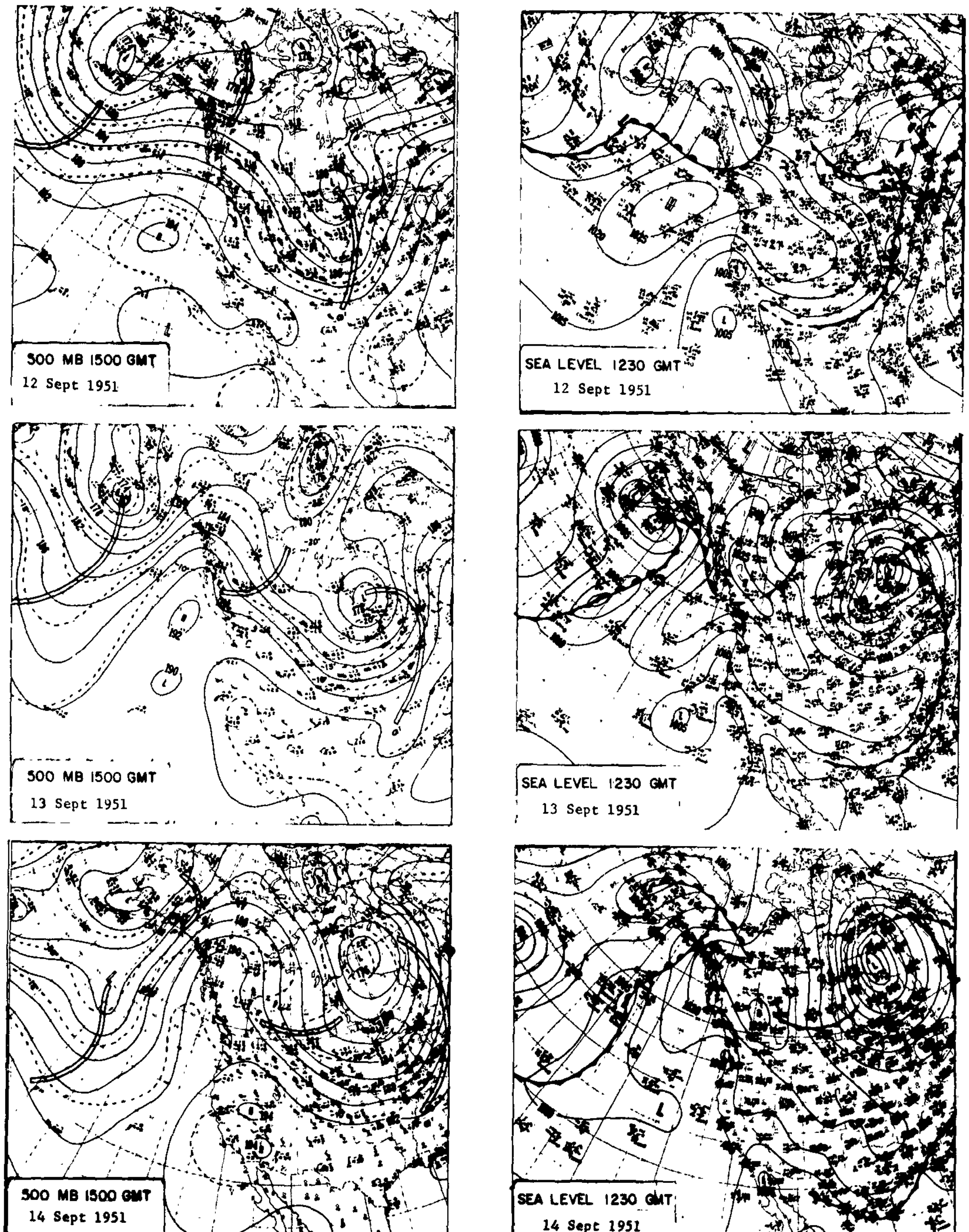


Figure 69. --Continued.

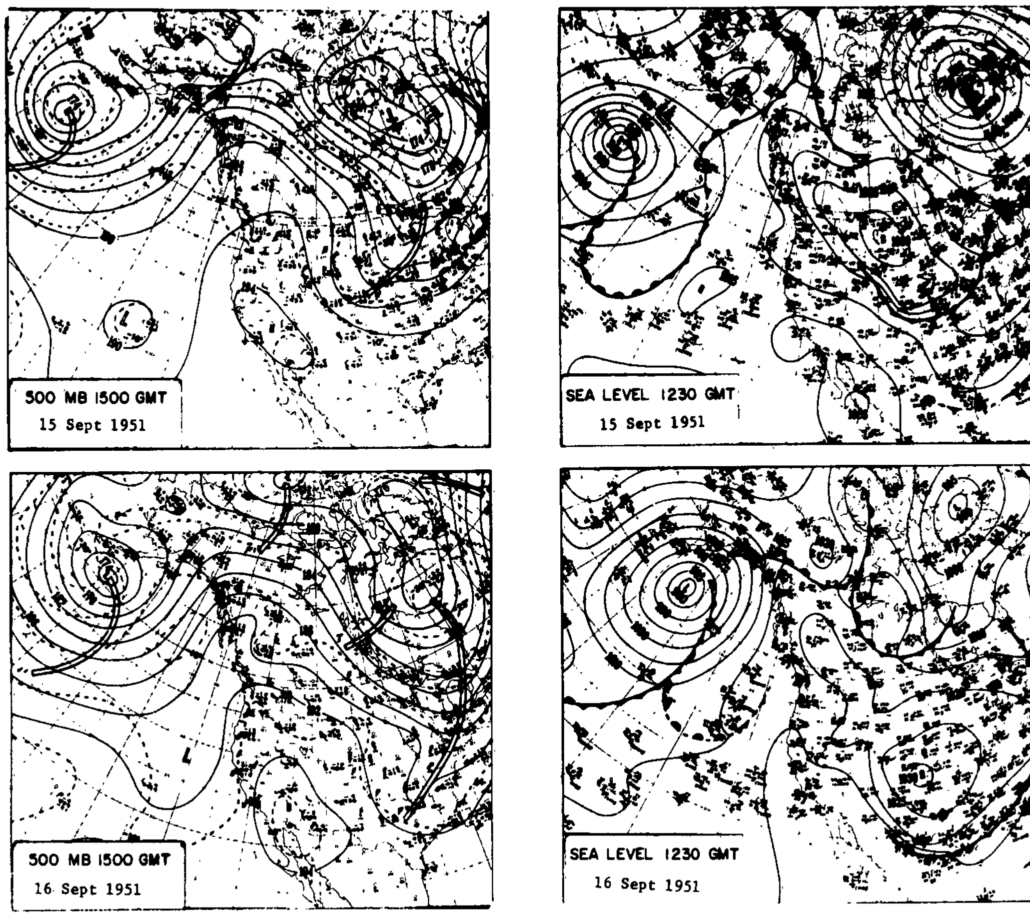


Figure 69. --Continued.

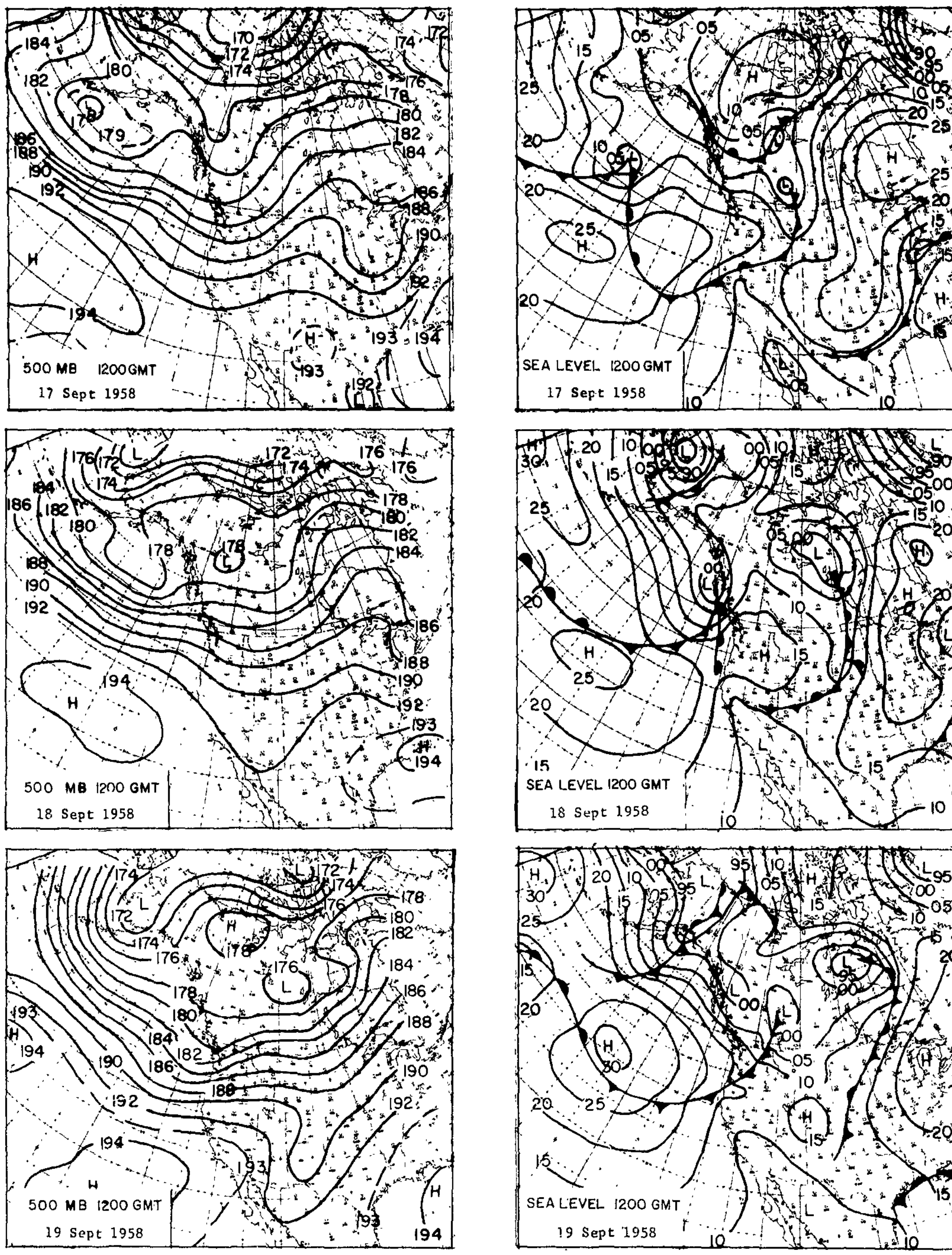


Figure 70.--Surface and 500 mb charts, September 17-23, 1958.

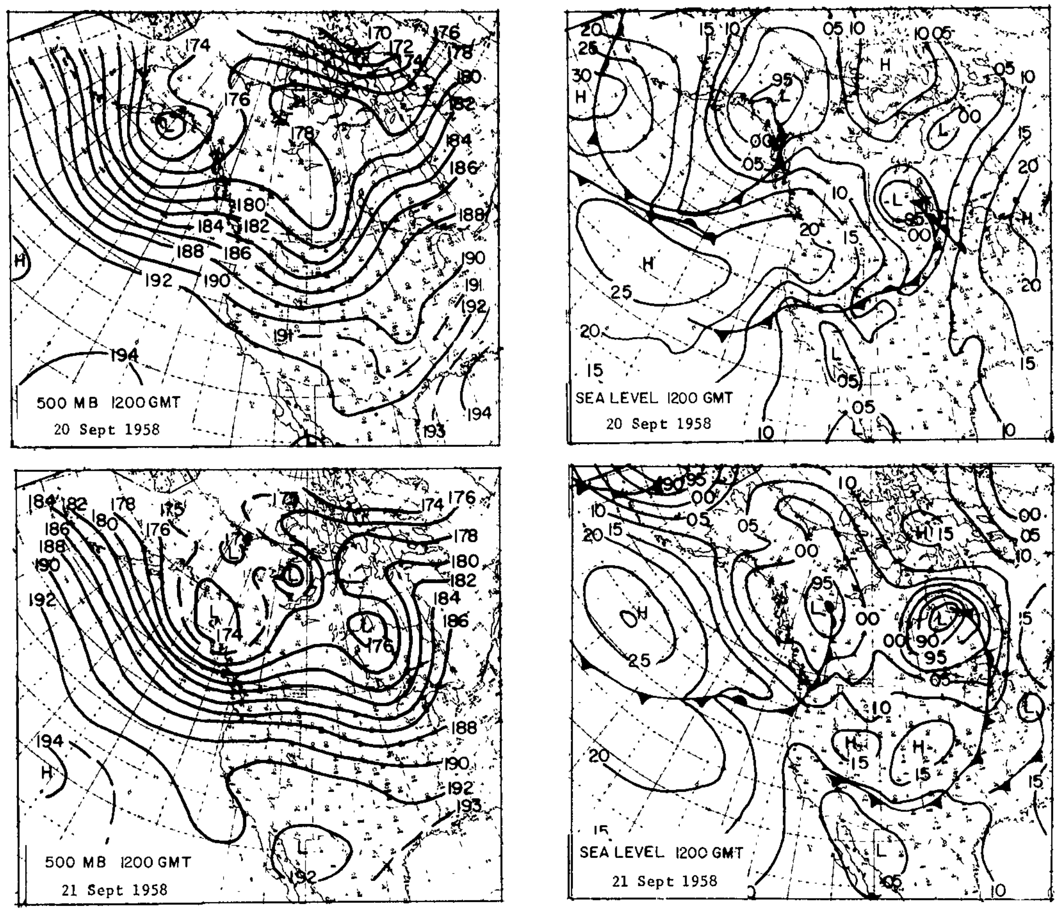


Figure 70. --Continued.

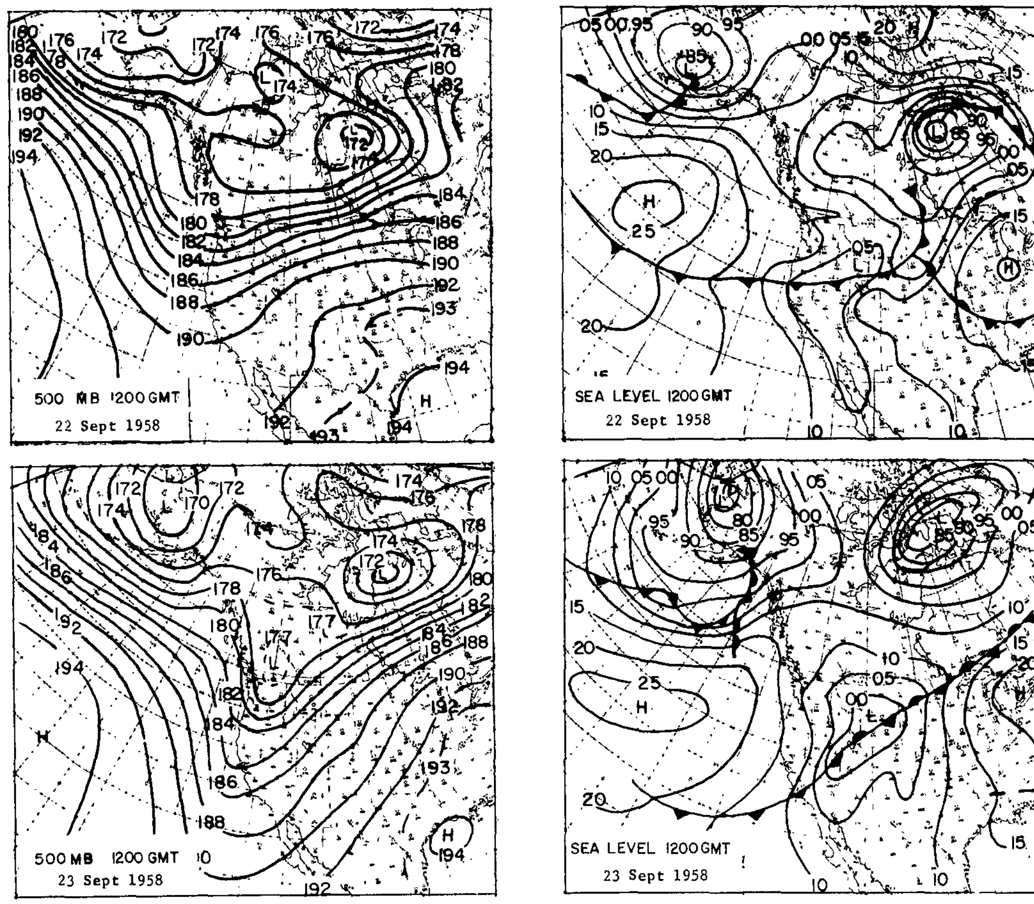
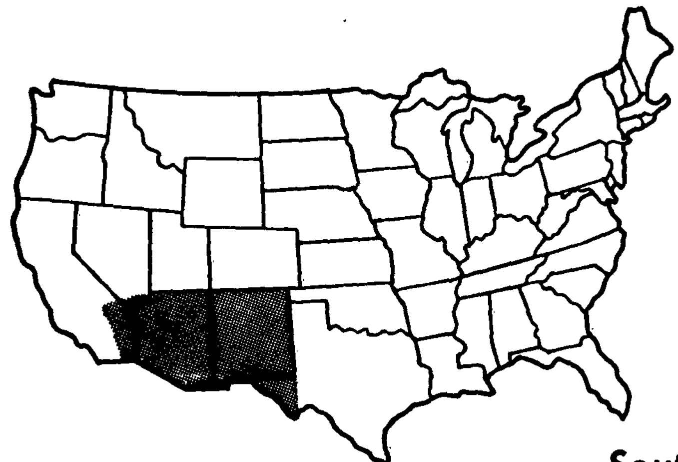


Figure 70. --Continued.



Southwest Region

The Southwest region includes the states of New Mexico, Arizona, extreme southern Nevada, and the western tip of Texas. The stations used to represent this region were Albuquerque and Roswell N. Mex., Prescott, Winslow, and Tucson, Ariz., and El Paso, Tex.

Critical fire weather occurs with greater frequency and persistence in this part of the country than in any other. Fire weather, of course, refers only to meteorological parameters; it does not consider the quantity or characteristics of natural fuels.

The Southwest is normally a region of relatively high temperatures, low humidities, light precipitation, and, during the spring, moderately strong daytime winds. Since these elements are the ones involved in critical fire weather, it follows that a relatively small change from the normal values can produce severe burning conditions. For this reason, the type or configuration of the synoptic weather patterns accounting for critical fire weather in this region are not as distinctive as over other portions of the country. Surface pressure patterns are usually very flat so that one must refer to the pattern aloft for clues to the relationship of broadscale circulation to periods of critical fire weather.

During the colder months of the year--November, December, January, and February--the frequency and persistence of severe burning conditions are at a minimum (table 42), but such conditions are by no means rare. A requisite for critical fire weather during this period is a moderate or strong surface wind. The direction of flow is of minor importance although the frequency of critical periods is higher when winds have a southerly component and hence bring higher temperatures. Thus, any weather pattern causing moderate to strong surface winds has the potential for starting an acute fire-weather period.

Table 42.--Seventy-fifth percentile of fire load index, by stations and months, Southwest region, 1951-60

Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Fire load index											
Prescott	7	12	22	29	50	73	37	18	31	24	14	9
Winslow	12	17	40	52	76	84	43	31	43	31	16	11
Tucson	15	20	31	43	52	52	31	18	35	31	24	18
Albuquerque	8	13	29	39	43	45	29	23	31	20	12	6
Roswell	22	34	60	66	63	60	40	34	37	32	22	20
El Paso	20	29	50	66	70	63	34	27	33	31	24	17

Table 43.--Number of days with a fire load index 50 and above, by station, Southwest region, 1951-60

Year	Prescott		Tucson		Winslow		Albuquerque		Roswell		El Paso	
	Fire load index equal to or greater than--											
	50	75	50	75	50	75	50	75	50	75	50	75
1951	20	3	27	3	71	36	51	21	79	35	57	20
1952	27	9	16	5	56	33	29	10	80	33	36	8
1953	44	22	51	19	67	36	37	18	110	44	69	29
1954	19	4	104	39	67	36	37	15	80	42	58	20
1955	61	26	57	24	71	47	35	13	70	44	73	32
1956	55	26	56	23	91	53	37	17	84	32	85	38
1957	8	1	44	13	31	13	16	5	51	28	52	24
1958	30	2	23	7	45	17	8	0	26	9	18	7
1959	25	12	64	16	62	31	9	2	42	17	68	28
1960	51	23	30	6	62	28	29	1	34	15	65	30
Total	340	128	472	155	623	330	288	102	656	299	581	236

Such periods are usually associated with the approach and passage of a relatively intense upper-air trough or surface frontal system involving dry air masses. Critical fire weather usually begins when the upper air trough or surface front approaches to within about 500 miles of the region and persists until the system is 200 miles or so past the region. The majority of these disturbances produce little or no precipitation over the lower elevations in the southern portions of the region, and only light amounts over the higher elevations of the northern portion. The upper-air patterns most often associated with these troughs aloft or surface frontal systems are the meridional and short-wave train patterns. Normally, wind speeds at the 500 mb level are of the order of 50 knots or more during severe burning periods.

Spring (March, April, and May) is the "windiest" season of the year, with moderate to strong daytime winds quite common. Thus, high wind speeds in addition to the normally rising temperatures and lowering humidities during this season account for an increasing frequency of severe burning periods and an annual peak in May or June (table 42).

During the summer (June, July, and August) the frequency and persistence of critical fire weather periods decreases from the annual maximum in June to the seasonal minimum in August. Temperatures remain consistently high throughout the season but winds are normally light. Relative humidity is at its annual minimum during the month of June over most of the region but is significantly higher during July and August. These latter two months constitute the period of maximum precipitation over most of the region. This precipitation is due to the northward and westward extension of the Bermuda anticyclone which results in a southerly or southeasterly flow of warm, moist, maritime tropical air over the region and convective shower activity.

As the shower activity diminishes, a seasonal maximum of periods of critical fire weather occurs in September. As temperature decreases during the fall, fire danger diminishes. Again, the passage of troughs aloft and surface frontal systems with their attendant moderate or strong surface winds become increasingly important in initiating severe burning conditions.

Since the normal level of fire danger is so high, as can be seen from the number of days with a fire load index of 50 or higher (table 43), it was not practical to investigate all of the periods of critical fire weather in this region. Consequently, only some of the most extreme cases were investigated; these were distributed through the year approximately as the total number of days of extreme fire danger are distributed. The total of 79 cases, involving 299 days, fell into three weather types, classified according to the upper-air pattern as Meridional Ridge-Southwest Flow, Short-Wave Train, and Zonal patterns.

Meridional Ridge - Southwest Flow Pattern

The Meridional Ridge-Southwest Flow pattern accounted for 24 percent of the cases studied.

The pattern aloft is characterized by a ridge of large amplitude (more than 15 degrees of latitude) located to the east of the region, usually near longitude 95°W but varying from 85°W to 105°W. The ridge is oriented mostly north-south, and the area of maximum wind in the ridge crest lies between 40°N and 50°N. The trough aloft is usually oriented north-northeast to south-southwest and lies between 110°W and 130°W. The region of maximum winds in the trough is normally between 30°N and 40°N. The location of the ridge and trough results in a southwesterly flow over the region at speeds usually of 40 to 50 knots but ranging from 20 to 70 knots.

At the surface, the east Pacific high pressure cell is evident with the leading edge often extending inland over the Pacific Northwest. High pressure also persists over most of the eastern half of the country. Between these two high pressure areas, there is a persistent trough of low pressure which usually extends from eastern Montana or the northern Plains south-southwestward to southern California. Normally, a series of low pressure centers and accompanying cold fronts moves eastward from the Aleutian Islands around the north side of the east Pacific High, southeastward over the coastal states into the West Coast trough, and then eastward or northeastward.

Although the fire danger remains high as long as the long-wave ridge and trough are in the positions indicated, peaks of critical fire danger occur with the passage of each short-wave trough and associated front. The fire danger drops below critical values only with the passage of the 500 mb trough or with its retrogression to a position west of 130°W. The normal sequence, however, is for the trough-ridge system to progress slowly eastward at 200 to 300 miles per day. Critical fire danger usually lasts 3 to 6 days.

A Meridional Ridge-Southwest Flow pattern is illustrated by the period May 30-June 3, 1955 (fig. 71). By May 30, the 500 mb ridge and trough pattern was positioned in such a way as to produce southwest flow over the region. The surface pressure pattern was flat and troughy over the region with a High to the east and another to the west. A weak front was approaching the region.

The entire pattern moved slowly eastward on the succeeding days. Southwesterly winds aloft increased and speeds reached 50 to 70 knots May 31 and June 1. The fire danger peaked on these days. At the surface, the approaching cold front dissipated but was followed by a secondary, stronger front. This front and the trough aloft passed through the region June 2 and 3, and fire danger decreased, except at El Paso, as temperatures lowered and winds became lighter.

The Short-Wave Train Pattern

The Short-Wave Train pattern accounted for 58 percent of the cases studied in the Southwest region. In many cases the distinction between a short-wave train and a meridional pattern is not clear-cut and it is a matter of judgement on the part of the meteorologist as to whether the pattern is one or the other. At times the two patterns occur together, as in the example below. The main belt of westerlies may have a meridional pattern, while to the south there may be a train of short-wave troughs and ridges moving eastward in a secondary belt of westerlies. This train of short waves appears to move independently of the main belt of westerlies for a time, and later may be absorbed into the main belt.

The position of the ridge and trough during the period of critical fire weather is similar to the Meridional Ridge pattern; that is, the ridge is to the east and the trough to the west. Both the wave length and the amplitude are smaller, however. The shorter wave length means that the ridge is farther to the west, usually between 95°W and 115°W, and the smaller amplitude results in the ridge crest being farther south, usually between 35°N and 45°N. The trough is normally in the same position and has the same orientation as in the Meridional Ridge pattern. This pattern produces southwest flow over the region at speeds of 20 to 40 knots.

At the surface, the east Pacific high pressure cell is evident, but low pressure exists in the Gulf of Alaska. High pressure is also found over most of the eastern half of the country. If the short-wave train involves the major portion of the belt of westerlies, a low pressure center and frontal system at the surface accompanies the short-wave trough. This system usually moves eastward around the top of the Pacific High, enters the West Coast, and continues eastward or southeastward. If the short-wave train is south of the main belt of westerlies, the short-wave trough may or may not be accompanied by a surface system.

The period of extreme fire danger begins when the trough aloft passes east of 130°W and ends when the trough, and the associated surface frontal system, if there is one, passes over the region. The trough-ridge system normally moves eastward 250 to 300 miles per day. The period of extreme fire danger lasts from 3 to 6 days.

The period September 19-22, 1956, is an example of a Short-Wave Train pattern (fig. 72). The 500 mb pattern September 19 showed a meridional trough over eastern North America and a ridge from the Southwest region northward through western Canada. Over the Pacific, however, a series of short-wave troughs was moving eastward south of the main belt of westerlies. The first trough had already passed 130°W, and south to southwest flow aloft was beginning to enter the region. At the surface, the pressure was low and the pattern very flat.

Fire danger peaked on September 20 as the trough aloft passed through the region. A second short-wave trough in the main belt of westerlies with an associated frontal system moved into the Pacific Northwest September 21. The two troughs became amalgamated September 22, and fire danger decreased as the combined trough aloft moved east of the district and a cooler air mass followed in the wake of the surface front.

The Zonal Ridge Pattern

The Zonal Ridge pattern accounted for 18 percent of the cases studied. As with the two previous patterns, critical fire weather occurs when the ridge aloft is to the east and the trough to the west of the region. Since this is a zonal pattern, the amplitude of the ridge is quite small. The ridge is usually found between $100^{\circ}W$ and $110^{\circ}W$; the maximum winds at the ridge crest are normally between $35^{\circ}N$ and $45^{\circ}N$. A closed contour at 500 mb is often situated over northern Mexico or the Texas Gulf coastal area.

The trough aloft is usually oriented northeast-southwest and is located between $115^{\circ}W$ and $125^{\circ}W$. The amplitude of the trough may vary considerably, but the greater the amplitude, the more distant the trough line must be from the Southwest to permit zonal flow over the region. The flow aloft over the region is generally from the west or west-southwest at speeds of 20 to 40 knots.

The pattern aloft over the Pacific may be zonal, meridional, or a block. The latter two, of course, are associated with a West Coast trough of large amplitude. Also in these cases the east Pacific high pressure area may extend far northward into the Gulf of Alaska. A broad trough of low pressure, primarily thermal in nature, is found over most of the country west of the Continental Divide. Fronts are occasionally present in the northern portion of this trough but rarely in the southern portion. The pressure gradient over the Southwest is generally very weak. High pressure is found over the southeastern states.

Factors related to critical fire weather with this pattern are: (a) the dryness characteristic of this pattern; (b) the nearness of the belt of westerlies to the region with apparently some transfer of momentum to the surface; and (c) the temporarily increased winds with the passage of weak short-wave troughs eastward, primarily to the north of the region.

Major changes in temperature and humidity do not occur with the Zonal Ridge pattern. The day to day fluctuations in fire danger are, therefore, related to changes in wind speed. The surface wind speed often fluctuates significantly from day to day although the speeds are generally lower than in the other two patterns. Maximum wind speeds are usually associated with the surface pressure gradient. In the spring, summer, and fall months this pressure gradient is normally directed east to west between the western portion of the surface High over the Southeast and the thermal trough over the lower Colorado River valley.

Fluctuations also appear to be related to the presence of moderate to strong winds aloft which in turn are related to the position and intensity of the trough to the west and the ridge to the east. When the trough aloft is approaching the region, winds aloft are moderately strong or increasing. When the ridge is near the region, winds aloft are relatively light.

September 15-17, 1954 (fig. 73) is an example of this pattern. In this example the flow is zonal over the United States but meridional over the Pacific. The trough along the West Coast and the ridge over the middle portion of the country resulted in a west-southwest flow over the Southwest region. At the surface, a thermal trough covered most of the western portion of the country September 15.

Flat short-wave troughs moving east-northeastward from the West Coast long-wave trough caused peaks in fire danger. Only temporary decreases in fire danger occurred behind the short-wave troughs. More-lasting relief does not occur until the long-wave trough passes east of the region. In this example the trough was still to the west on September 17. The extreme fire danger decreased on September 19 when the trough aloft and a surface front passed through the region.

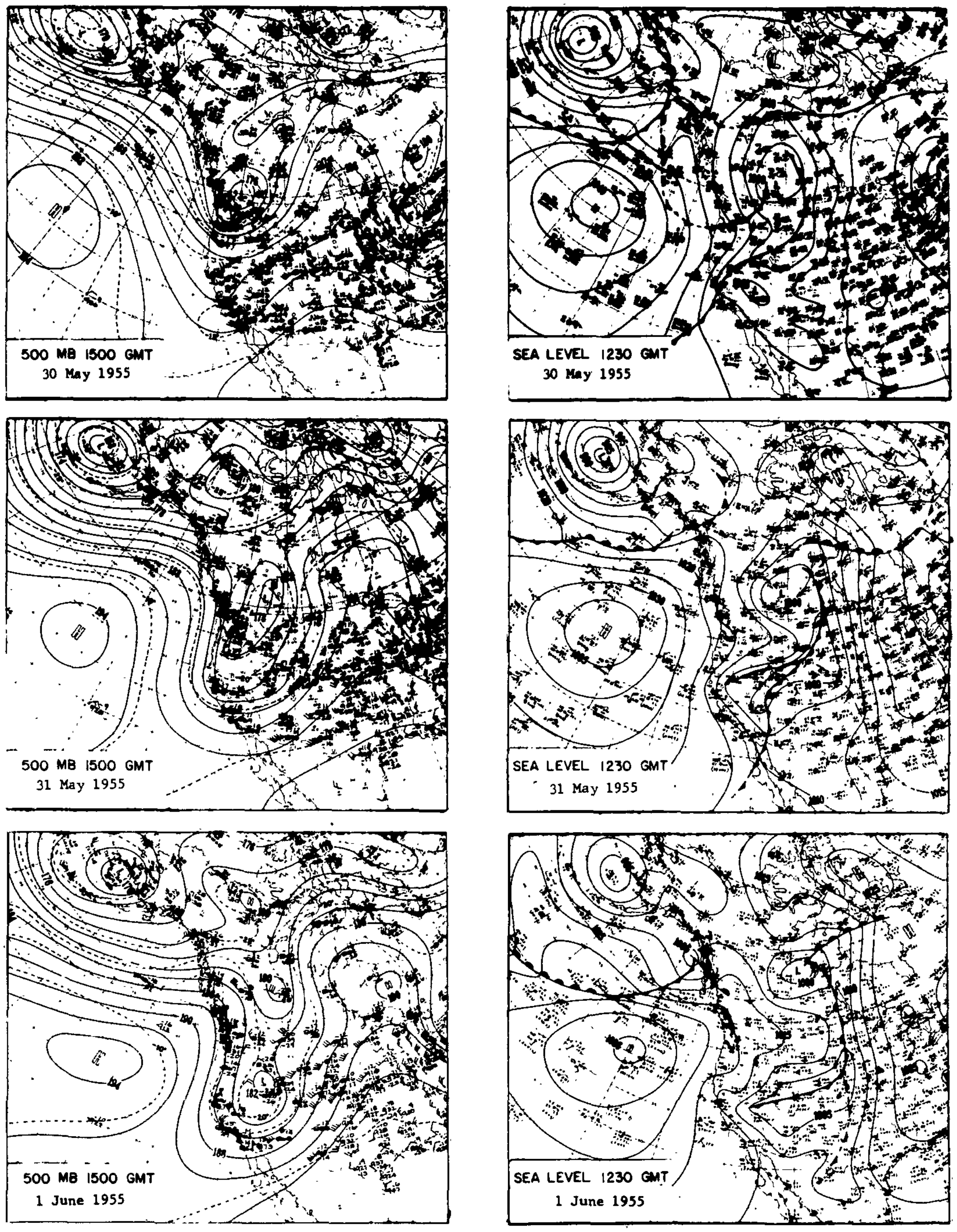


Figure 71. --Surface and 500 mb charts, May 30-June 3, 1955. The most critical days were May 31 and June 1.

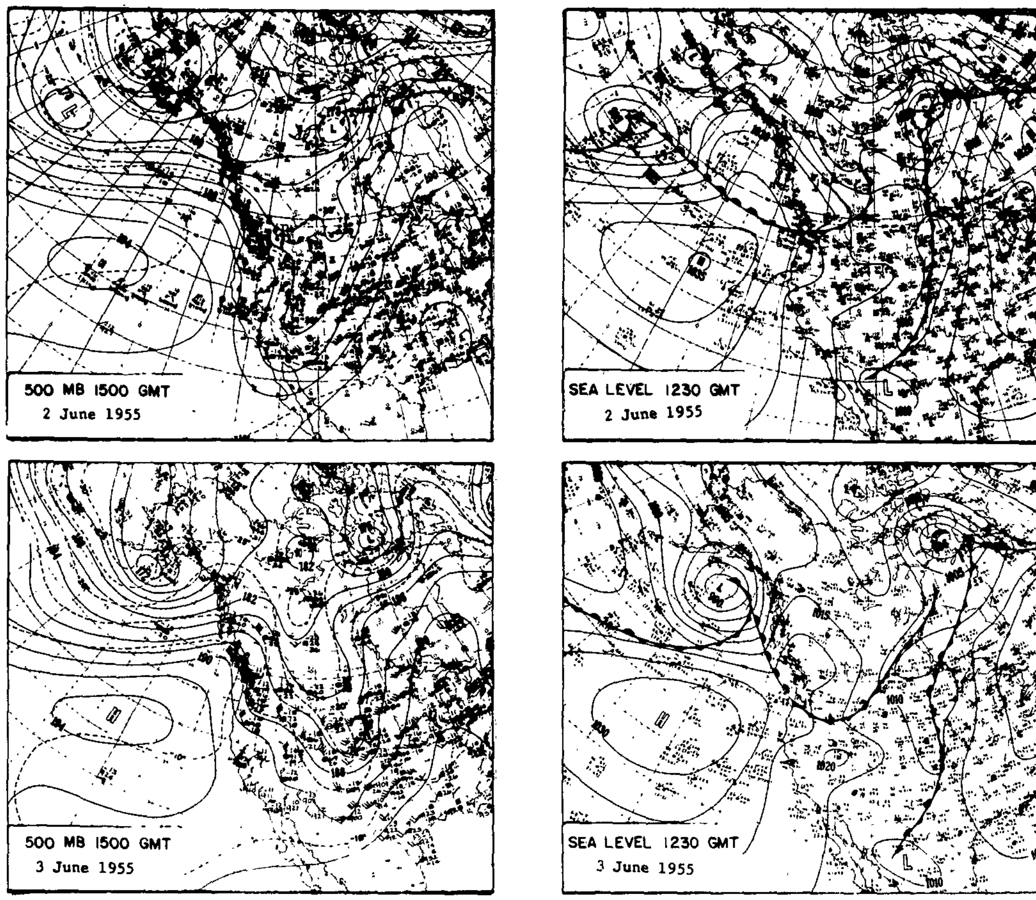


Figure 71. --Continued.

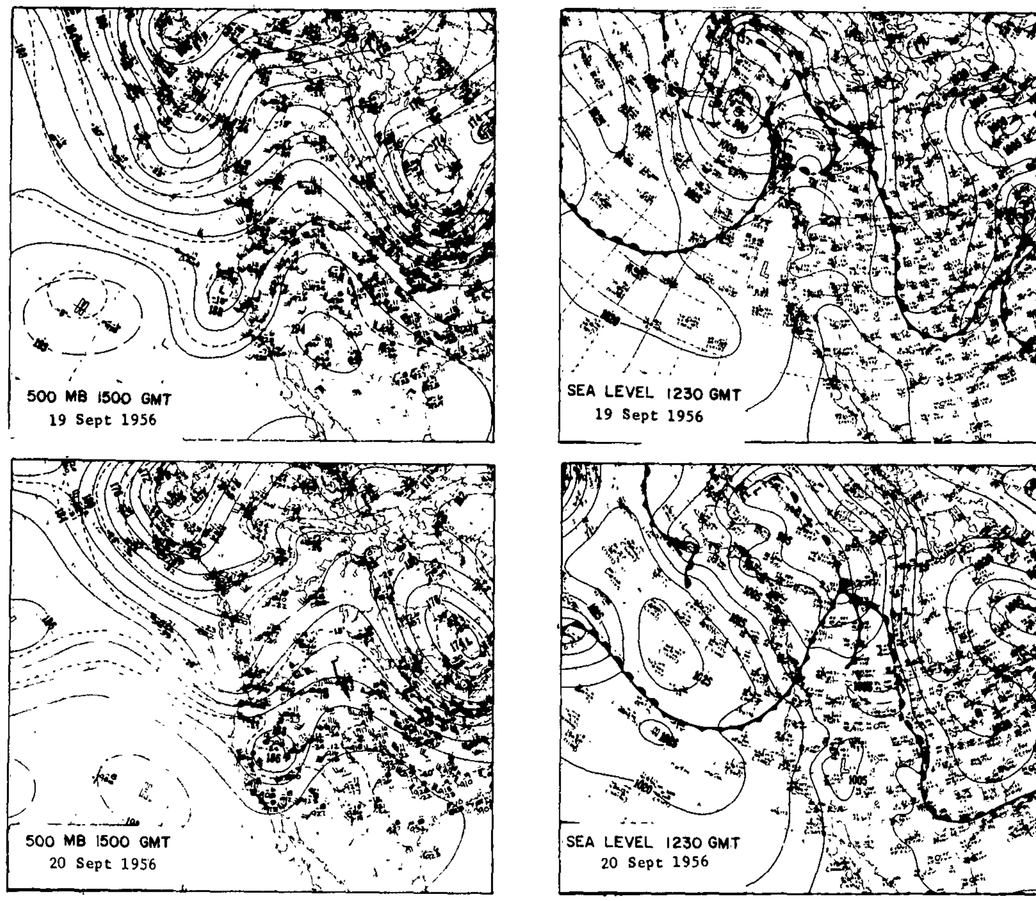


Figure 72. --Surface and 500 mb charts, September 19-22, 1956. Fire danger peaked at Prescott on September 19 and in most of northern part of region September 20 and 21.

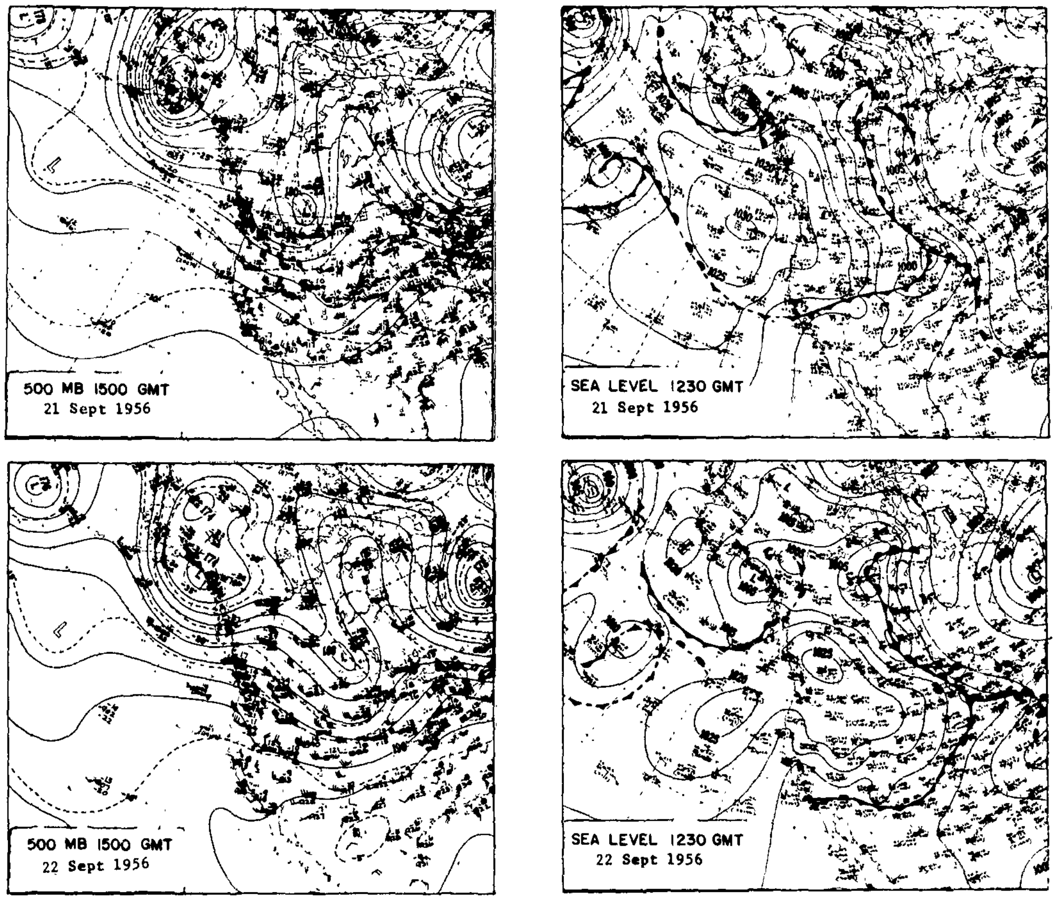


Figure 72. --Continued.

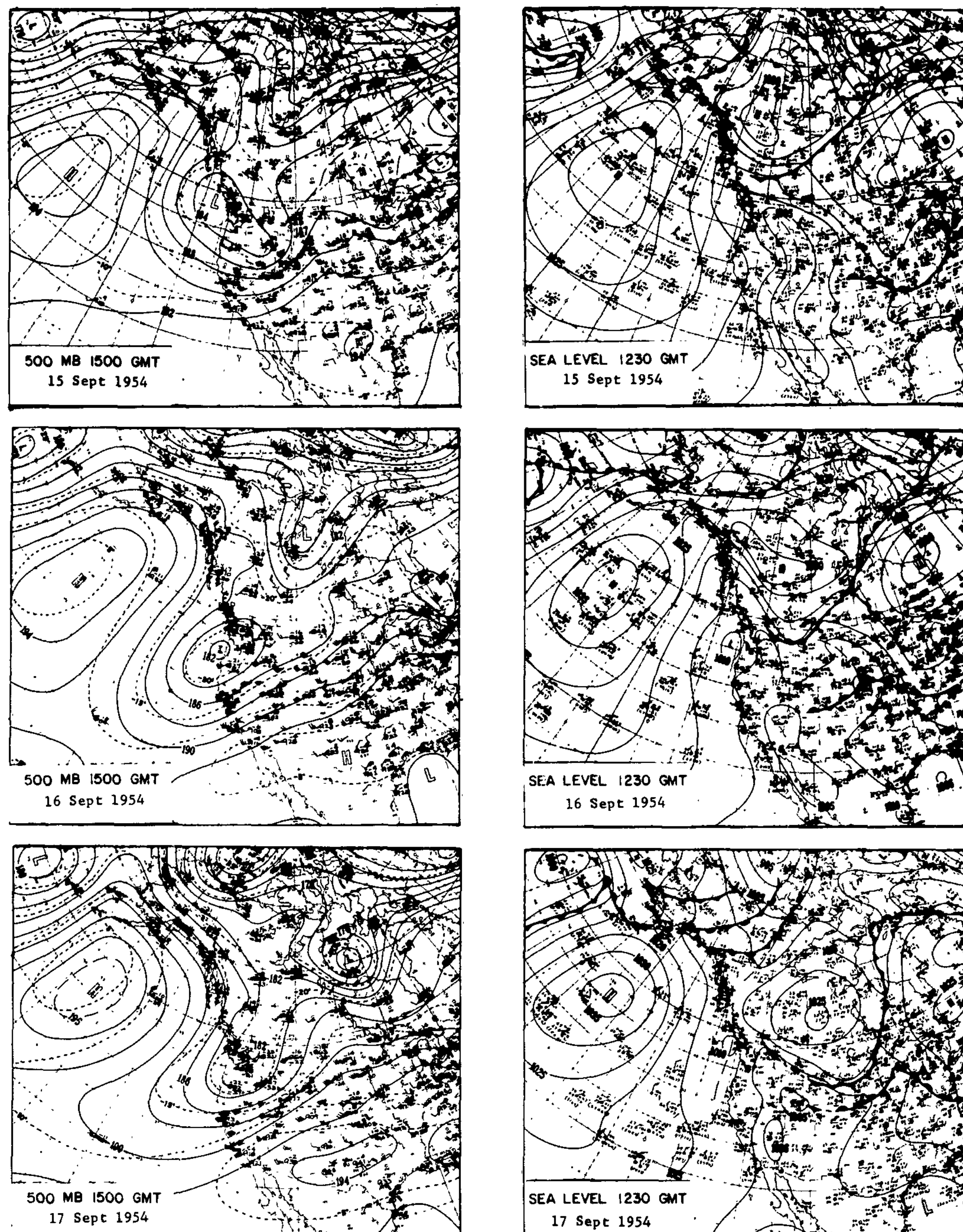


Figure 73.--Surface and 500 mb charts, September 15-17, 1954. Fire danger was highest September 15 and did not decrease significantly until September 19.

Pacific Northwest Region

The Pacific Northwest region includes those portions of Washington and Oregon west of the crest of the Cascade Mountains.

The climate is mild and of maritime origin. Most of the air masses moving across the region have been over the Pacific from one to several days. As a result, winter minimum and summer maximum temperatures are greatly moderated. These air masses are usually laden with moisture and are responsible for the abundance of rainfall occurring over most of the region. Annual rainfall amounts average 70 to 120 inches along the coast and west slopes of the Olympic and Coast Ranges. At the lower elevations in the Puget Sound area of Washington and in the broad valleys between the Coast and Cascade Ranges in Oregon the average is about 35-40 inches. Local exceptions to this distribution are the interior valleys of southwest Oregon and the area immediately to the northeast of the Olympic Mountains in Washington where the annual rainfall averages about 20 inches. Slightly more than 40 percent of the annual precipitation falls during the winter months, roughly 25 percent each in the spring and fall, and less than 10 percent during the summer months.

The weather stations used to represent the region were Medford, North Bend, and Eugene, Oregon, and Olympia and Seattle, Washington. Three of these stations were not very useful in helping to select periods of critical fire weather because of their location near the ocean or Puget Sound. The selection of periods for study was made primarily on the basis of fire load indexes of 22 or higher. The distribution of fire load index is shown in table 44. Values 17 and above are included to provide more information on the distribution. There were 202 days with a fire load index of 22 or above at any station during the 10-year period.

Table 44.--Number of days with fire load index 17 and above by station,[1] Pacific Northwest region, 1951-60

Year	Olympia			Seattle			Medford			Eugene		
	Fire load index equal to or greater than--											
	17	22	37	17	22	37	17	22	37	17	22	37
1951	1	1	0	1	1	0	38	29	2	41	27	9
1952	0	0	0	0	0	0	3	1	1	18	7	2
1953	1	1	0	0	0	0	0	0	0	12	7	1
1954	0	0	0	0	0	0	6	3	1	4	2	0
1955	1	1	0	1	1	0	32	21	3	9	3	0
1956	2	2	0	0	0	0	14	5	1	15	13	2
1957	0	0	0	0	0	0	28	13	1	12	8	1
1958	1	1	0	0	0	0	12	7	0	23	16	3
1959	0	0	0	0	0	0	24	17	1	17	9	3
1960	2	2	1	0	0	0	29	16	1	22	14	1
Total	8	8	1	2	2	0	186	112	11	173	106	22

1/ The station at North Bend reported no days of FLI 17 or above.

Table 45.--Number of days with fire load index 22 or above, by months, Pacific Northwest region, 1951-60

Month	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	Total
Jan.	0	0	0	0	0	0	0	0	0	0	0
Feb.	0	0	0	0	0	0	0	0	0	0	0
Mar.	0	0	0	0	0	0	0	0	0	0	0
Apr.	2	0	0	0	0	0	1	0	0	0	3
May	0	0	1	0	1	1	0	0	0	0	3
June	11	0	0	0	7	0	4	0	1	0	23
July	15	3	2	4	7	7	5	4	11	13	71
Aug.	12	1	4	0	6	5	2	9	10	6	55
Sept.	9	2	0	0	3	5	6	6	2	6	39
Oct.	0	1	0	1	0	1	0	3	0	1	7
Nov.	0	0	0	0	0	0	0	0	0	1	1
Dec.	0	0	0	0	0	0	0	0	0	0	0
Total	49	7	7	5	24	19	18	22	24	27	202

The fire season in the Pacific Northwest region usually extends from June through September. Occasionally the season is longer, beginning in April or lasting into November, and serious forest fires have occurred in all months of the year.

From June through October, days of fire load index 22 or above at any station occurred about 13 percent of the time (table 45).

From a tabulation of days of high fire danger, 64 periods were selected for study. These periods covered 153 of the days of high fire danger, and included occasional days within the periods with a fire load index slightly lower than 22. The remainder of the high fire danger days were single-day occurrences at one station only.

Periods of critical fire weather occur only when the region's normally marine-type climate is interrupted by the occasional invasion of a continental air mass or by subsiding air from aloft over the Pacific anticyclone. During these periods warm, dry, low-level winds blow across the region from the east, northeast, or north. They are produced when surface pressures are lower along or just off the coast of Washington and Oregon than they are to the north or east. This surface pressure differential must be present to produce critical fire weather periods.

The conditions necessary to produce high fire danger in this region are closely related to the surface pressure pattern. The cases of high fire danger were grouped into two synoptic weather types although there was some variation within each group. These types are: Pacific High with Post-frontal or East Winds and Northwest Canadian High with Post-frontal or East Winds.

Pacific High with Post-frontal or East Winds

Since more than three-fourths of the high fire danger periods studied (table 46) occurred with the Pacific High type, including the region's most severe fire weather, this type may be considered first in importance.

Table 46.--Number of cases with fire load index 22 or above, by months and pattern, Pacific Northwest region

Pattern	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Pacific High	0	0	0	3	1	7	18	11	8	0	2	0	50
NW Canadian High	0	0	0	0	0	1	2	4	5	1	1	0	14
	0	0	0	3	1	8	20	15	13	1	3	0	64

The surface pressure pattern necessary to produce high fire danger with the Pacific High type can occur with either meridional or zonal flow aloft. Of the 50 cases of this type, 26 had meridional flow and 24 had zonal flow. In the meridional cases the meridional ridge was usually oriented north-south along or just off the coast. Upper winds over the region were then from a northerly direction, sometimes from the northeast or even east if the ridge extended into western Canada. In 10 of the 26 meridional cases, the ridge aloft was inland and the winds over the Pacific Northwest region were southwesterly, or occasionally southerly. If the pattern aloft was moving, the high fire danger period was short-lived, but there were cases where the pattern was stagnant and the high fire danger persisted for some time.

The Pacific High cases with zonal flow aloft tended to be short because of the steady movement eastward of the surface systems. In many of the cases classified as zonal, a blocking pattern was found over the Pacific ocean. The zonal pattern extended from just east of the block into the Pacific Northwest and eastward across the northern portion of the country.

Regardless of the flow pattern aloft, an offshore component in the surface wind over the region is necessary to produce high fire danger. In the typical case a rather extensive surface high pressure area develops over the Gulf of Alaska or the northeastern Pacific Ocean. Following the passage of a short-wave trough aloft, a "nose" of this High fills in behind the weak surface front and pushes inland over British Columbia. As this high pressure ridge settles southward over eastern Washington and eastern Oregon, the pressure pattern becomes favorable in the post-frontal area for easterly surface winds to move over and through the Cascade Mountains and spill over western Washington and western Oregon.

If a portion of the Pacific high pressure cell breaks off and moves into the northern Intermountain area, an east to west pressure gradient is maintained over the Pacific Northwest region. Lower pressures, which have a tendency to develop on the lee side of a mountain range, coupled with warm surface temperatures resulting from clear skies and adiabatic warming, will cause the "California thermal trough" to extend northward along or just off the Oregon-Washington coastline. A large surface pressure differential (as much as 10 to 12 mb per 100 miles in extreme cases) may develop between the eastern and western portions of Washington and Oregon and cause strong easterly winds to blow. If a meridional ridge aloft is located near the coast, much of the air in the easterly wind flow may come from aloft and reach the surface over eastern Washington and eastern Oregon through subsidence. When this air reaches the surface, it is extremely warm and dry. In crossing the Cascades the air is further warmed as it descends the western slopes and becomes the hot, desiccating "easterly winds" that bring critical fire weather to the Pacific Northwest region.

Strong easterly winds seldom occur in July and the first half of August. The rather weak offshore gradient in the east wind cases occurring

during this period is effective primarily in preventing the marine air from moving inland. This allows hot, dry weather to persist over the region. Earlier and later in the season the wind speeds over the region are 20-35 miles per hour in a typical east wind case. In the fall of the year particularly, the break-off of the Pacific High may actually increase in intensity after it reaches the northern Intermountain areas and steadily increase the gradient between it and the coast over a period of several days. In extreme cases winds in excess of 80 mph have been measured. Typically during the peak danger period of one of these east wind onslaughts, afternoon temperatures will soar to over 100° and relative humidities will drop to 15 to 20 percent, and in extreme cases to less than 10 percent.

The duration and severity of an east wind period depends on the strength, depth, and extent of the high pressure ridge which moves inland. This, in turn, is related to the flow pattern aloft. The surface High associated with a zonal pattern tends to be less intense. A weak case may be considered as one lasting only 2 or 3 days and having north to east winds of 10-20 mph. These winds will be observed through the Cascade Mountains but only rarely penetrate the Coast Range.

The most severe fire weather is associated with a meridional pattern in which a closed Low aloft develops off the coast of central and southern California as the ridge builds inland over the Pacific Northwest and British Columbia. This pattern is often referred to as a "West Coast Block" and one which may persist as long as a week to 10 days with strong east winds blowing over nearly all of western Washington and western Oregon and for some distance out to sea.

The high fire danger period is usually terminated by a short-wave trough aloft and associated surface frontal system. Ahead of the front the surface wind returns to an onshore direction and brings maritime climate back to the region.

In predicting high fire danger periods associated with the Pacific High type, the forecaster should look for the development of the Pacific high pressure cell into the northeastern Pacific Ocean and the approach of a surface front oriented in such a way that the winds behind it will have an offshore component. Then, if the frontal passage is accompanied by little or no precipitation, high fire danger can be expected in the post-frontal area and again when a break off of the Pacific high pressure cell reaches the northern intermountain area. Since the most severe fire danger is associated with a meridional ridge off the coast, indications for the ridge development should be looked for. One good indication is pronounced deepening of the trough upstream. Another is the movement of warm air northward over the Gulf of Alaska. Some of the best indicators of ridge development in this area are provided by the 500 mb rawinsonde observations over the weather ship "Papa" located at 50°N and 145°W in the Alaskan Gulf. Strong ridge development is in progress if this observation shows the wind to be from the southwest, the height of the 500 mb level to be rising, and the temperature 10°C or more above temperatures over Kodiak and Anchorage and still rising.

The breakdown of the ridge aloft is indicated by the shifting of the 500 mb winds at Papa to westerly in response to an active short-wave trough.

Two examples illustrating high fire danger with Pacific Highs have been selected. The first period, July 25-28, 1956 (fig. 74) is one in which the upper-air pattern was initially zonal then became more meridional with the trough off the coast and the ridge inland. July 25, a weak surface cold front moved into the Pacific Northwest and a nose of the Pacific High pushed in behind it. The amplitude of the pattern aloft increased July 26, while the surface front slowed down and became nearly stationary. The gradient flow behind the cold front had an offshore component.

A deep trough aloft formed near the coast July 27 and produced southwesterly winds over the region. Offshore surface flow continued in parts of Oregon, and the fire load index at Eugene reached its peak at 32 for this period. Following are some fire weather observations taken at 1630 P.s.t. on that day in western Oregon.

Station	Wind (Dir.)	Wind (Mph)	Relative Humidity (Percent)
Dallas	NE	4	32
Yellow Butte	N	8	26
Table Mountain	NE	3	50
House Mountain	N	18	46
Trask	NW	4	56

July 28 the trough aloft began moving inland and brought an end to the high fire danger period July 29. Surface winds became northwesterly and brought maritime air into the region.

The second period, September 10-11, 1957 (fig. 75) is one in which the upper-air flow was meridional, with the ridge off the coast and northerly flow over the Pacific Northwest region. September 10, the ridge pattern aloft was well established off the West Coast and into northwest Canada. A closed Low had formed off the California coast. At the surface a nose of the Pacific High had pressed inland into British Columbia and northern Washington behind a cold front which had moved through the region several days earlier. Easterly winds brought a fire load index of 49 to Eugene and 31 to Medford.

A portion of the Pacific High broke off and moved southeastward on September 11. The thermal trough extended northward from California through western Oregon and into western Washington. Although warm weather remained in most of the region, the wind speeds dropped sufficiently

to bring temporary relief from the high fire danger. This period was followed by one associated with a Northwest Canadian High.

The Northwest Canadian High with Post-frontal or East Winds.

Surface winds with an offshore component in the Pacific Northwest region occur much less frequently with a Northwest Canadian High than with a Pacific High. Less than one-fourth of the cases were of this type. When they do occur, conditions are very similar to those of the Pacific High type and for that reason the Northwest Canadian High type will be treated only briefly.

One of the principal differences between the two types is that the Northwest Canadian High periods tend to occur most frequently in August and September while Pacific High periods are most frequent in July.

The pattern aloft is usually meridional with a well-developed ridge off the coast and northerly winds over the Pacific Northwest region. In rare cases the ridge may be inland. In a few cases the flow aloft was zonal.

In the typical case, a front, oriented nearly east-west, passes through the region moving in a southerly direction. The front is followed by a High from Northwest Canada. In the area to the rear of the front the isobars are oriented east-west and the pressure gradient is steep so that strong easterly winds blow over the region. As the High moves southeastward an offshore gradient is maintained and high fire danger persists until this gradient relaxes and allows marine air to penetrate inland.

In predicting high fire danger periods from a Northest Canadian High, the indications to look for are similar to the Pacific High type. The main difference, of course, is that a High must be present in northwest Canada and the flow aloft must be favorable for the High to move southward and affect the Pacific Northwest region.

The period September 12-15, 1957 (fig. 75) illustrates the type. September 12 a blocking pattern developed in the eastern Pacific with the ridge extending into northwest Canada and northerly flow over the region. At the surface, the western end of a cold front was moving through the region and a High from northwest Canada moved into the northern Rockies. This High, combined with the thermal trough along the Pacific Coast, produced strong easterly winds over the region September 13. Some reinforcement of the surface winds may have resulted from the winds aloft which had become more northeasterly over the region. Eugene had a fire load index of 35. Following are some fire weather observations taken at 1630 P.s.t. on that day in northwest Oregon.

	Wind (Dir.)	(Mph)	Relative Humidity (Percent)
North Fork	SE	10	19
House Mountain	NE	20	23
Green Peter	E	7	17
Euchre Mountain	E	31	29

The pattern continued on September 14 but on the next day a weak front moved into the region and brought with it maritime air and a temporary relief from high fire danger.

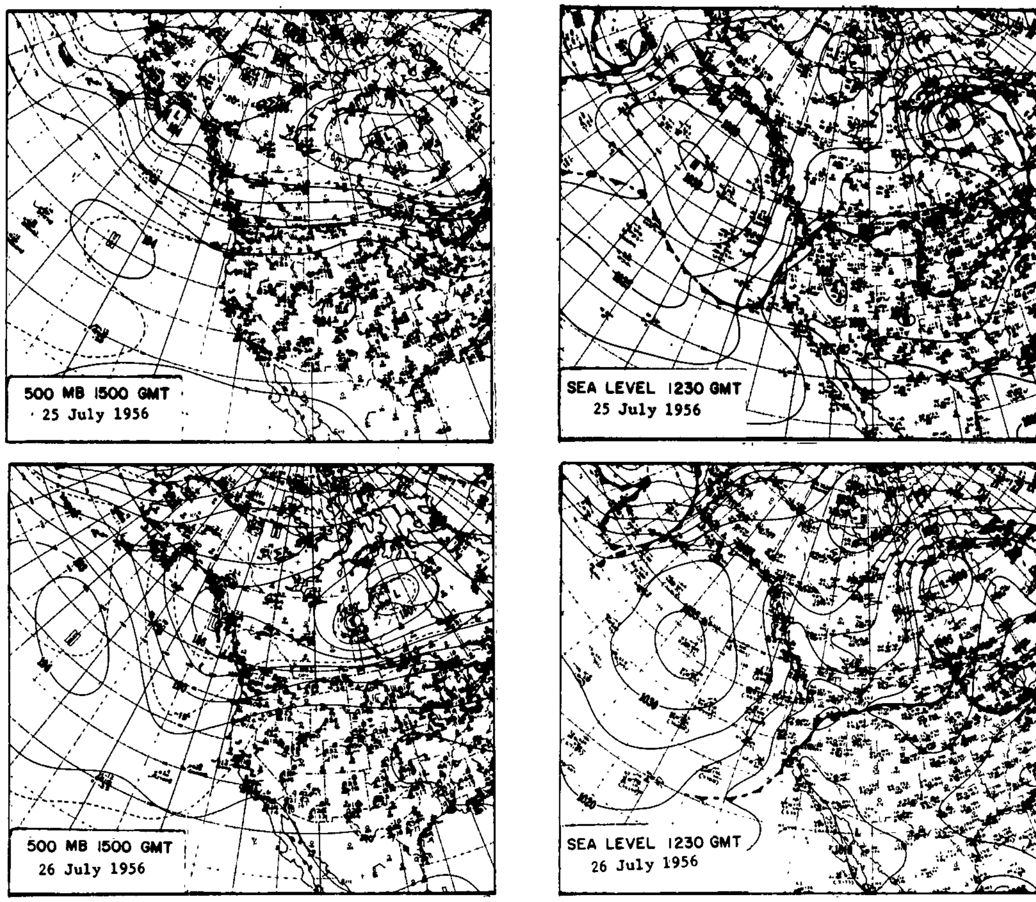


Figure 74. --Surface and 500 mb charts, July 25-28, 1956

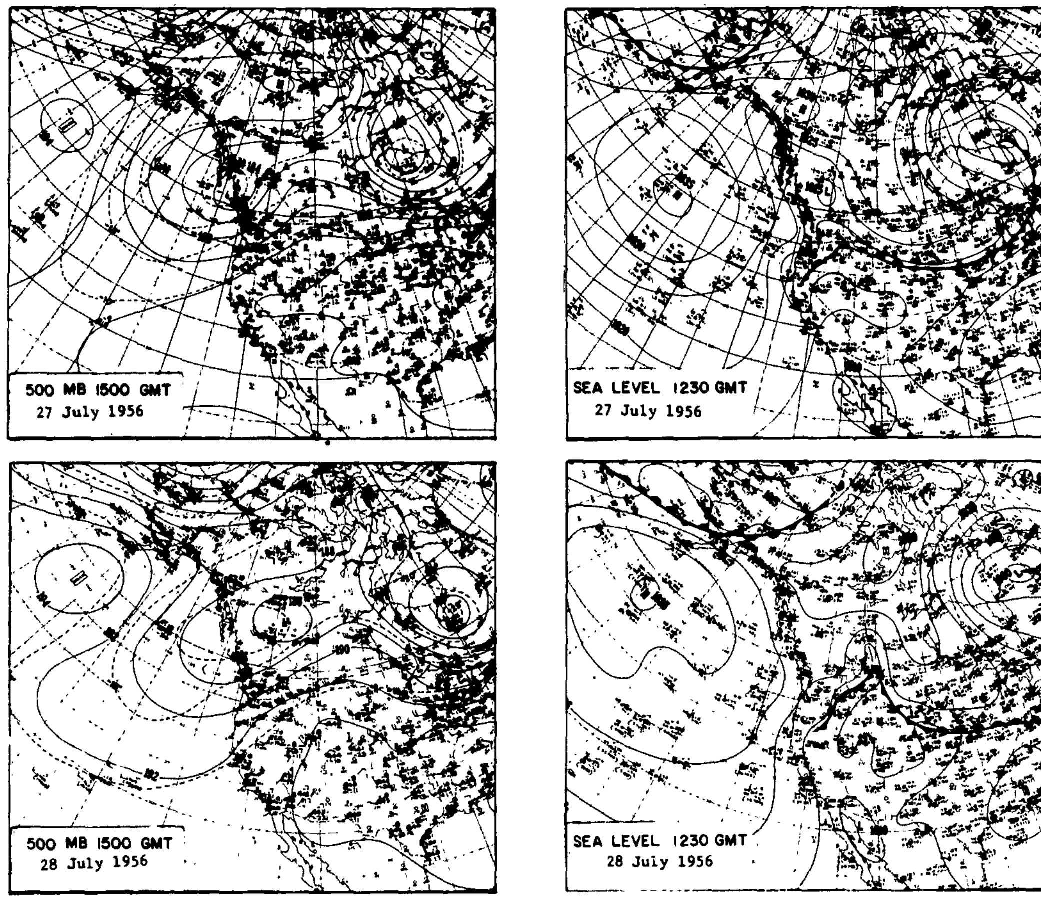


Figure 74. --Continued.

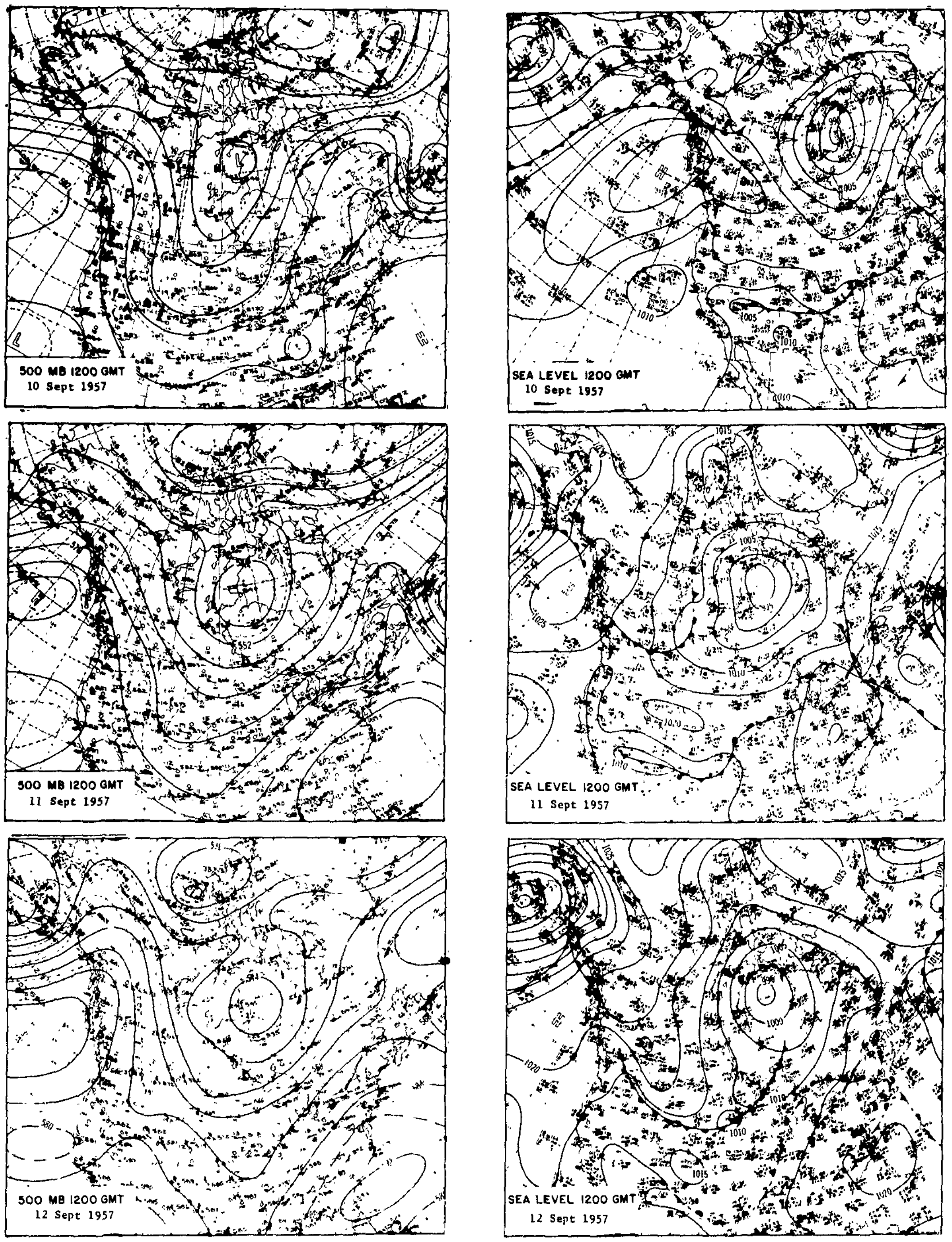


Figure 75. --Surface and 500 mb charts, September 10-15, 1957

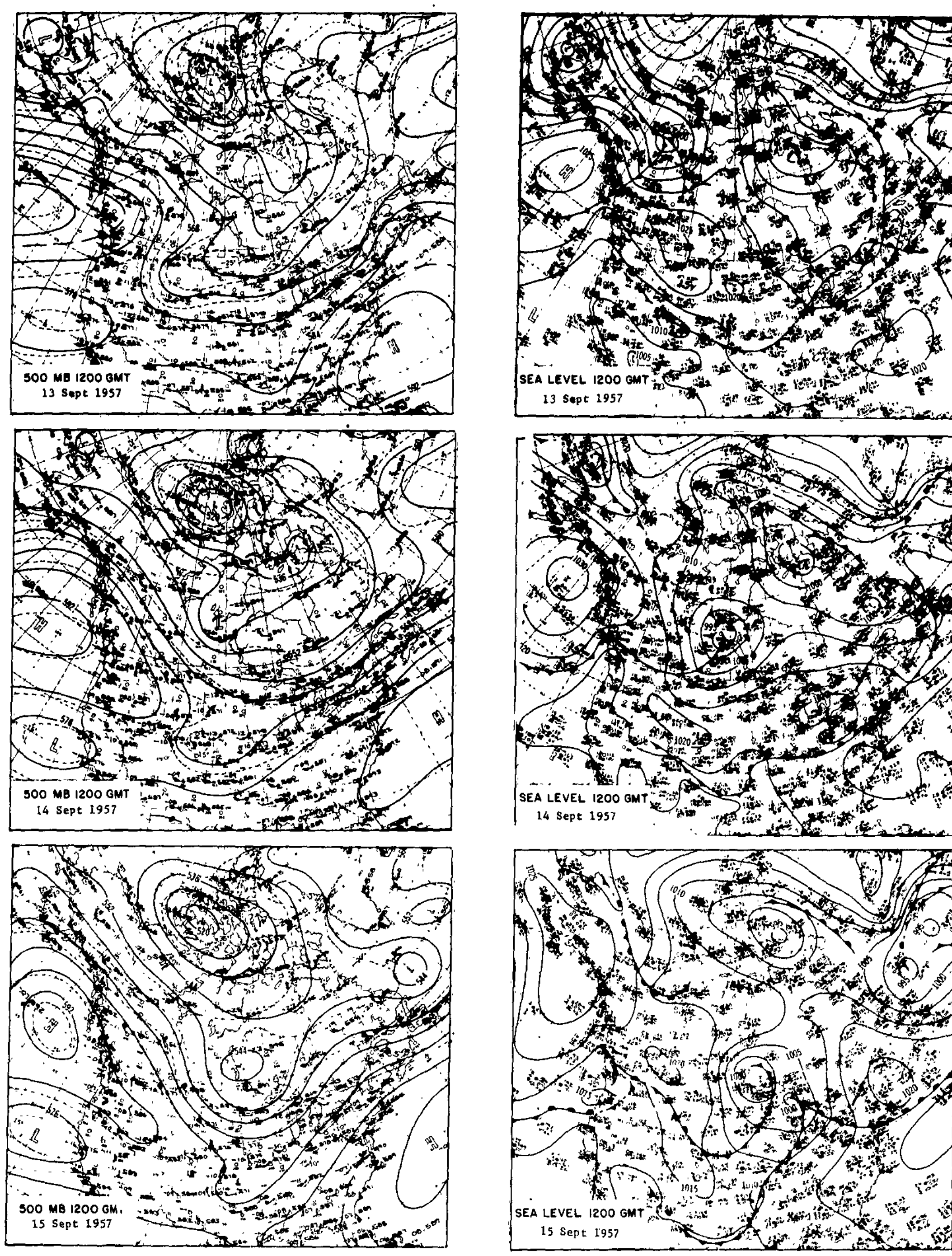
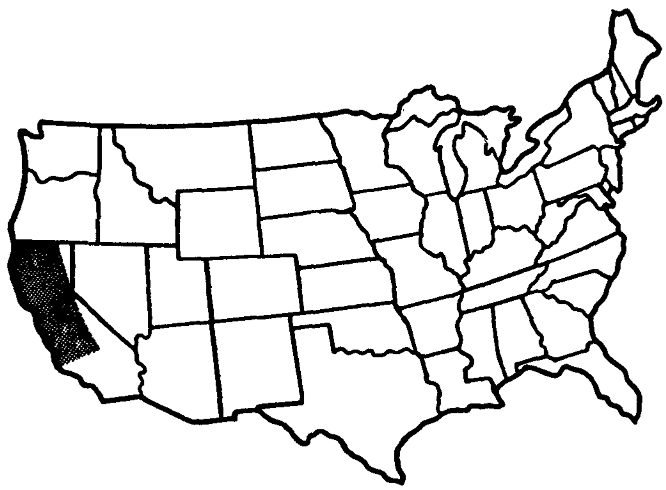


Figure 75. --Continued.



Northern and Central California Region

Northern and Central California in this study includes the area from the Oregon border to the Tehachapi Mountains and from the coast to the crest of the Sierra Nevada. The five weather stations used to represent this region on a year-round basis were: Mt. Shasta, Sacramento, Blue Canyon, Fresno, and Oakland. In addition, fire danger indexes were available for more than 200 seasonal fire weather stations. These data resulted in a complete picture of fire danger.

This region has a complex climate because of the topography and the nearness of the Pacific Ocean. During the summer months, the water along the coast is colder than that either farther south or farther north. This difference is due to upwelling of water from ocean depths to replace water carried away from the coast by the prevailing wind. The cold water in turn cools the air lying over it, and when the cool, humid marine air is carried inland by the sea breeze or by gradient wind flow, it produces a cool maritime climate.

The marine layer is normally quite shallow and is topped by a subsidence inversion above which the warm dry subsiding air of the east side of the Pacific anticyclone is found. Hence while lower elevations along the coast may be cool and humid, higher elevations in the Coastal Ranges are warm and dry.

The large Central Valley of California (containing both the Sacramento and San Joaquin Valleys) is isolated from the coastal marine air by the Coast Ranges and is normally hot and dry in the summertime. The principal access that marine air has to the Central Valley is through the Carquinez Straits on the east side of San Francisco Bay.

Table 47.--Number of days with fire load index 22 or above by month, Northern and Central California region, 1951-60

Month	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	Total
Jan.	0	0	0	0	0	0	0	0	0	0	0
Feb.	0	0	2	0	0	1	0	0	0	0	3
Mar.	15	0	0	1	2	1	6	0	2	0	27
Apr.	2	2	1	1	3	2	1	0	2	2	16
May	5	8	2	7	7	2	0	0	10	8	49
June	8	4	6	9	9	15	13	2	19	21	106
July	22	4	20	20	21	14	17	3	24	19	164
Aug.	21	12	11	17	29	13	18	6	20	25	172
Sept.	17	6	10	12	17	17	15	13	10	21	138
Oct.	11	2	12	7	9	3	2	4	9	8	67
Nov.	1	3	3	1	5	4	2	2	3	0	24
Dec.	0	0	0	1	0	1	0	0	2	0	4
Total	102	41	67	76	102	73	74	30	101	104	770

Table 48.--Number of days with fire load index of 22 or above, by station, Northern and Central California region, 1951-60

Year	Mt. Shasta			Blue Canyon			Sacramento			Oakland			Fresno			Total station days		
	Fire load index equal to or greater than--																	
	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50
1951	52	9	1	33	4	0	31	12	4	1	0	0	24	1	0	141	26	5
1952	12	0	0	11	0	0	18	6	3	1	0	0	11	0	0	53	6	3
1953	15	3	0	28	2	0	34	8	4	5	3	2	11	2	1	93	18	7
1954	9	1	0	40	3	2	40	15	9	7	2	1	32	6	0	128	27	12
1955	34	5	0	35	15	3	59	15	2	2	0	0	35	1	0	165	36	5
1956	6	0	0	12	2	0	43	9	0	4	1	1	26	1	0	91	13	1
1957	11	0	0	26	4	1	28	11	0	3	1	0	33	4	0	101	20	1
1958	1	0	0	5	0	0	10	3	0	4	1	0	14	1	0	34	5	0
1959	5	0	0	22	6	0	46	7	1	14	1	0	52	6	2	139	20	3
1960	4	0	0	33	8	3	29	9	4	4	2	2	78	5	0	148	24	9
Total	149	18	1	245	44	9	338	95	27	45	11	6	316	27	3	1,093	195	46

Marine air which does enter by this route does so in a shallow layer and is soon modified by solar insolation and becomes warm and relatively dry. Only when the marine layer is deep enough to flow over the Coastal Ranges does marine air that is but slightly modified flood the Central Valley and lower the fire danger there.

To the north of the Central Valley are the rugged Siskiyou Mountains and Cascades and along its east side, the Sierra Nevada. These mountains also play an important part in the way that synoptic-scale weather patterns affect fire weather in the region. Air flowing from the north or east into the Central Valley descends the slopes of these mountains. In so doing it is warmed and dried adiabatically and reaches the lower slopes and the valley as a desiccating wind.

The precipitation pattern in California is that of a Mediterranean climate--dry summers and wet winters. Nearly all of the precipitation falls from September through May, but even during these months there may be long dry periods. This precipitation comes from storms moving in from the Pacific Ocean. The only summertime precipitation comes in the form of thundershowers, primarily in the mountain areas. Moisture for thunderstorm activity usually is advected from the Gulf of Mexico across the Southwest and northward along the Sierra. In northern California, summertime thundershowers also result when closed, cold Lows aloft move into that area and produce very unstable conditions.

The average annual precipitation varies considerably throughout the region. It ranges from as little as 5 inches in the southern end of the San Joaquin Valley to 20 to 30 inches in the northern Sacramento Valley, and from 40 to 50 inches at high elevations in the southern Sierras to 80 to 90 inches in the northern Sierras. Similarly, in the Coast Range the annual average varies from 20 to 30 inches in the south to 100 to 110 inches in the north.

With this seasonal weather pattern, the fire season in northern and central California usually extends from June through September. Occasional periods of high fire danger are found during many years in March, April, and May in the spring and in October and November in the fall (table 47). The years 1952 and 1958 were comparatively easy; 1951, 1955, 1959, and 1960 each had over 100 days of high fire danger. This variability is evident in fire load indexes of 22 or above at each of the five stations (table 48) as well as for all five combined.

Occurrence of large fires follows closely the pattern of high fire danger days. Frequency of Class E fires on the National Forests in Northern and Central California by months for 1951-1960 was as follows:

Month	No.
March	1
April	1

Month	No.
May	2
June	9
July	30
August	59
September	35
October	7
November	1
Total	145

More than 85 percent of the large fires burned during the July-September period.

A study of the surface and 500 mb charts for the periods of high fire danger revealed four principal synoptic patterns and types. They are:

1. Subtropical High Aloft
2. Meridional Ridge--Southwest Flow
3. Pacific High--Post-frontal Type
4. Great Basin High

Since the Great Basin High ordinarily follows a frontal passage, it was grouped with the Pacific High Post-frontal type to study frequencies throughout the year (table 49). A few cases of high fire danger occurred under conditions not definitely related to one of the principal types.

Subtropical High Aloft

The Subtropical High Aloft is the pattern causing the highest fire danger in this region. The flow pattern is usually meridional but may be zonal. In either case the belt of westerlies is far to the north--above 40°N--in western North America, and the closed Subtropical High Aloft is located over the Southwest.

When this High is well-developed it effectively blocks moisture from the Gulf of Mexico from reaching California.

This pattern is a stagnant one and produces the worst and most prolonged critical fire-weather periods in the region. Warming takes place because of subsidence in the High aloft and because of intense solar radiation.

Table 49.--Number of cases and days with fire load index 22 and above by months and synoptic type, Northern and Central California region, 1951-60

Month	Subtropical High Aloft	Meridional Ridge Southwest Flow	Pacific High--Post-frontal and Great Basin High	Miscellaneous	
				Pre-frontal	Cold Low or trough aloft
January					
Cases	0	0	1	0	0
Days	0	0	1	0	0
February					
Cases	0	0	2	0	0
Days	0	0	2	0	0
March					
Cases	0	0	9	0	0
Days	0	0	11	0	0
April					
Cases	0	0	15	0	0
Days	0	0	18	0	0
May					
Cases	0	0	24	0	0
Days	0	0	48	0	0
June					
Cases	5	2	25	3	0
Days	16	7	57	3	0
July					
Cases	14	7	18	2	0
Days	111	25	43	3	0
August					
Cases	12	6	13	2	6
Days	132	25	29	2	16
September					
Cases	10	6	28	3	3
Days	53	30	66	3	7
October					
Cases	1	1	22	2	0
Days	1	3	26	2	0
November					
Cases	0	0	16	1	1
Days	0	0	19	1	1
December					
Cases	0	0	3	1	0
Days	0	0	3	2	0

Humidities become extremely low. This pattern causes summertime heat waves in California which may last several weeks and at times longer than a month. The 500 mb heights are very high--near 19,300 or 19,400 feet--and during extreme cases 19,600.

A definite pattern on the surface map is usually not discernible with the Subtropical High Aloft except for the presence of the normal thermal trough through the Central Valley.

The mere presence of a Subtropical High Aloft over California is not a guarantee of high fire danger. The source of the air mass must be known. If the original air mass is part of the subtropical High over the Southwest, then high fire danger can be expected because of high temperatures and low humidities. However, if the original air mass is part of the subtropical High over the Pacific Ocean, then the case is marginal. High fire danger may or may not develop.

A times the fire danger may fluctuate, particularly in the coastal regions and parts of the Central Valley, because of the occasional penetration of marine air and stratus clouds into these areas. In some cases a batch of moisture originally associated with a tropical storm off Baja California works its way northward over California during this pattern and produces thunderstorms in the mountain areas, and lower temperatures and higher humidities generally in the state.

During periods of persistent high fire danger due to a stagnant subtropical High over southwestern North America, the upper-air flow to the north, along the Canadian border, may change from one pattern to another. During the process, cold fronts may enter British Columbia and be followed by portions of the surface Pacific high pressure cell. Trailing ends of these fronts may reach as far south as northern or central California. The strong winds accompanying each frontal passage will cause the fire danger to become extreme for a day or so.

Except for temporary fluctuations, relief does not arrive until the Subtropical High Aloft pattern either breaks down or moves eastward. The breakdown may be caused by the approach of a vigorous short-wave trough or by a broadscale change in the general circulation. If the pattern aloft shifts eastward, strong southwesterly winds between the upper-level ridge to the east and the trough to the west will affect the mountainous areas of northern and central California and create a critical fire situation until the trough aloft moves over the region.

The surface and 500 mb charts for August 30-September 7, 1955 (fig. 76) show a classic example of this weather pattern. Actually the Subtropical High had been a recurring pattern since the latter part of July. The position of the High aloft on August 30 produced extremely high temperatures and critical fire weather in much of the West. Both the High aloft and the pressure pattern at the surface in California showed only minor changes on the succeeding days during which extreme fire danger persisted.

Substantial relief did not appear until September 14 when the pattern finally broke down.

Meridional Ridge - Southwest Flow Pattern

When a meridional ridge aloft is located near longitude 90°W to 100° W, a trough off the West Coast near 130°W, and the belt of southwest winds between the two passes over Northern and Central California during the summer and early fall months, high fire danger can be expected in the Sierra and the eastern half of northern California. The strong winds aloft are felt at higher elevations on the surface and produce the high fire danger.

The coastal strip, the mountains of the Coast Range, and the Central Valley will experience relatively low fire danger with this pattern. The pattern is favorable for extensive penetration of marine air inland, often accompanied by stratus clouds. The marine layer may be fairly deep with this type, but areas with high fire danger are found above the influence of marine air.

Sometimes the trough off the West Coast may strengthen when the wave length decreases. The ridge over the United States remains stationary while the next ridge upstream moves eastward. This causes an increase in the upper-air flow which in turn increases the fire danger.

Peaks of high fire danger may also be produced by the southwest flow pattern when short-wave troughs move out of the Pacific Coast trough and pass through the region. With each short-wave trough passage, the winds increase enough, particularly at higher elevations, to cause brief periods of critical fire weather.

The fire danger decreases with this pattern when the trough aloft moves closer to the coast and the winds over the region diminish. When the trough aloft approaches Northern and Central California, the cloudiness and weather associated with such troughs also decrease the fire danger.

An example of this pattern was the period of September 15-19, 1956 (fig. 77). In this case the Low aloft off the West Coast originated as part of a block pattern, then became a closed Low south of the main belt of westerlies, and finally was absorbed into the westerlies. The surface pressure pattern was very flat throughout the period with nothing more than a broad thermal trough extending up through California.

Fire danger was high in many mountain areas September 15, 16, and 17 as strong southwesterly winds affected these areas. The fire danger lowered September 19 as the trough aloft began to move inland.

The Pacific High - Post-frontal type

When a significant short-wave trough aloft with its associated surface cold front moves into the Pacific Northwest or northern California, it is usually followed at the surface by a portion of the Pacific high cell. This causes a northerly, post-frontal wind that brings critical fire weather to the Northern and Central California region.

The upper-air pattern may be meridional, block, short-wave train, or zonal. Usually the long-wave ridge position is over the eastern Pacific and the trough in western United States, but there are cases of cold front passages when the long-wave trough is off the coast. The important factor is whether or not the Pacific High pushes inland into the Pacific Northwest or northern California behind the cold front. This requires a rather vigorous short-wave trough aloft followed by a short-wave ridge.

For this pattern to be effective the surface High in the Pacific should be 1030 mb or higher and located between 30°N and 45°N and 130°W and 145°W.

If a long-wave trough exists in western United States, the short-wave trough accompanying the surface front may deepen it significantly and cause the formation of a surface Low in Nevada. As a result of these events, the winds aloft over the region become more northerly and the surface pressure pattern creates a strong gradient between the nose of the Pacific High and the thermal trough in California. Strong northerly winds blow down the Sacramento Canyon and drainages in Siskiyou, Modoc, and Lassen counties. This air flowing from higher to lower elevations produces a foehn effect and extreme fire danger. Later, if the nose of the High presses further inland, the surface wind becomes more northeasterly, and drainages in the western Sierras become affected. High fire danger is usually found in the Sacramento Valley with this pattern, but the San Joaquin Valley often is not affected because fronts tend to dissipate as they move inland and southward. Usually the high fire danger with this type lasts only 1 or 2 days, but when a Nevada Low forms, the period is prolonged to 4 or 5 days. Frontal passages may come through in rapid succession, with only brief periods of relief between. The fire danger ends when the pressure gradients relax and the winds diminish.

If the flow aloft is a short-wave train type, then the high fire danger usually lasts only one day because of the speed with which the front and its trough aloft move through the region. The danger may be extreme, however.

If the flow aloft is zonal or if the long-wave trough is off the coast instead of inland, frontal passages may be frequent but the fire danger is marginal and brief.

The strong buildup of surface pressure inland behind the cold front in the Pacific Northwest does not occur. The surface isobars behind the front will more likely be oriented north-south rather than east-west and the downslope and offshore flow is not pronounced.

In all cases the principal factor causing high fire danger is the wind. First, the strong and turbulent winds with the frontal passage itself boost the fire danger. Then in the post-frontal area, if the isobars are oriented east-west, strong north to northeast winds blow down the mountain slopes and canyons from higher to lower elevations and produce a foehn effect. In strong cases this pattern may influence the entire area between the Sierra and the coast. If the isobars are oriented north-south instead of east-west, the high fire danger does not develop in the post-frontal area.

In some cases the wind which causes high fire danger does not set in until the day after the front has passed. This appears to be the case when there is considerable lag between the surface front and the short-wave aloft. The short-wave ridge does not enter the Pacific Northwest or British Columbia until a day later than the surface front. Only after this ridge has entered the continent does the upper-air pattern lend support to the surface pattern and produce the strong wind.

Frontal passages may seem to be rare in California during the summer, but periods of high fire danger occur with this type quite frequently during that season as well as during the spring and fall. Often these are the trailing ends of cold fronts passing through to the north; the winds they produce cause extreme fire danger when the fuels are dry. Few high fire danger periods are found with this type in the winter season, not because the type doesn't occur, but because frontal passages are usually accompanied by precipitation in the winter. Higher elevations are generally snow-covered.

Charts for October 22-25, 1954, illustrate this weather type (fig. 78). October 22, as a trough aloft crossed the Pacific Coast and a surface cold front passed through the region, the fire danger was below critical levels. In this case the pressure gradients were weak with the frontal passage whereas many times with this type strong gusty winds accompany the front. High fire danger did not appear until October 23 when the trough aloft deepened over the western states causing very strong northwesterly winds. At the surface, a portion of the Pacific High extended into British Columbia and the Pacific Northwest and established a strong gradient between it and the front. Isobars in the post-frontal area were oriented northeast-southwest and favored offshore flow. The fire load index rose to 65 at Sacramento and 40 at Oakland on that day.

High fire danger continued October 24, with the pattern shifting only slightly eastward. Blue Canyon reported a fire load index of 22, Sacramento 66, and Oakland 29.

On October 25 the pressure gradient decreased and the fire danger dropped temporarily to below critical levels.

The Great Basin High Type

The Great Basin High type frequently follows the Pacific High--Post-frontal type. After passage of a cold front and its short-wave trough aloft, a portion of the Pacific high pressure cell breaks off and moves into the Great Basin, also called the Intermountain Region, where it stagnates. The resulting strong pressure gradient between the Great Basin High and the thermal trough in California produces strong easterly winds across the Sierra Nevada. These winds have a foehn effect on the west side of the Sierra, and are sometimes called Mono winds. Mild temperatures and low relative humidities combined with the strong wind may produce extreme fire danger. When the thermal trough is forced westward to the coast then high fire danger occurs along the coast as well as in the interior of the region.

The flow pattern aloft is usually meridional--with a ridge off the west coast and a deep trough, frequently with a cold Low, over the Great Basin or the Southwest. The surface High is steered into the Great Basin by the northwesterly flow aloft. At times the flow aloft becomes northerly and pulls down a High from northwest Canada into the Great Basin. This air mass is colder and drier than Pacific air masses and is a potentially greater threat. Fortunately for this region, northwest Canadian air masses get into the Great Basin only during the late fall, winter, and spring months when at least the higher elevations are snow covered. Even Pacific Highs seldom get into the Great Basin during the summer months. (To the Southern California region the Great Basin High is a greater threat and develops highly hazardous conditions known as the Santa Ana type.)

The high fire danger period ends when the pressure gradient relaxes and the winds diminish.

The period October 13-16, 1954 (fig. 79) illustrates the Great Basin High type for Northern and Central California. The flow aloft on October 13 was favorable for steering a portion of the Pacific High from the Pacific Northwest into the Great Basin. The Pacific High had followed the passage of a cold front.

The High grew to 1035 mb by October 14 and created a strong pressure gradient across the region between it and a trough off the California coast. Oakland's fire load index rose to 35 on that day. The High center and the area of strong pressure gradient remained in place the following day; Blue Canyon had a fire load index of 29 and Fresno 31.

Although the High weakened October 16, high fire danger still remained. On the following day the gradient weakened enough that the winds diminished and the fire danger decreased.

Miscellaneous Types

Besides its occurrence in the post-cold-front area, high fire danger occasionally occurs in the southwesterly flow in the pre-frontal area. Here strong winds and rising temperature cause the danger. It almost always lasts only one day.

A few cases of high fire danger were also found when cold closed Lows or troughs aloft moved into northern California. The cause of the high fire danger may be a combination of factors. Cold air aloft makes the atmosphere unstable which in turn contributes to a turbulent, windy condition near the surface. Some parts of the region, particularly high elevations, may be affected by the southwesterly winds aloft on the southeast or east side of the Low or trough, similar to the southwesterly flow pattern described above. Usually when there is a trough or closed Low aloft, the marine layer is deep and fire danger is low along the coast. This situation occurred August 11, 1956 (fig. 80), and the resulting fire load indexes were: Mt. Shasta 17, Blue Canyon 20, Sacramento 31, Oakland 0, Fresno 24.

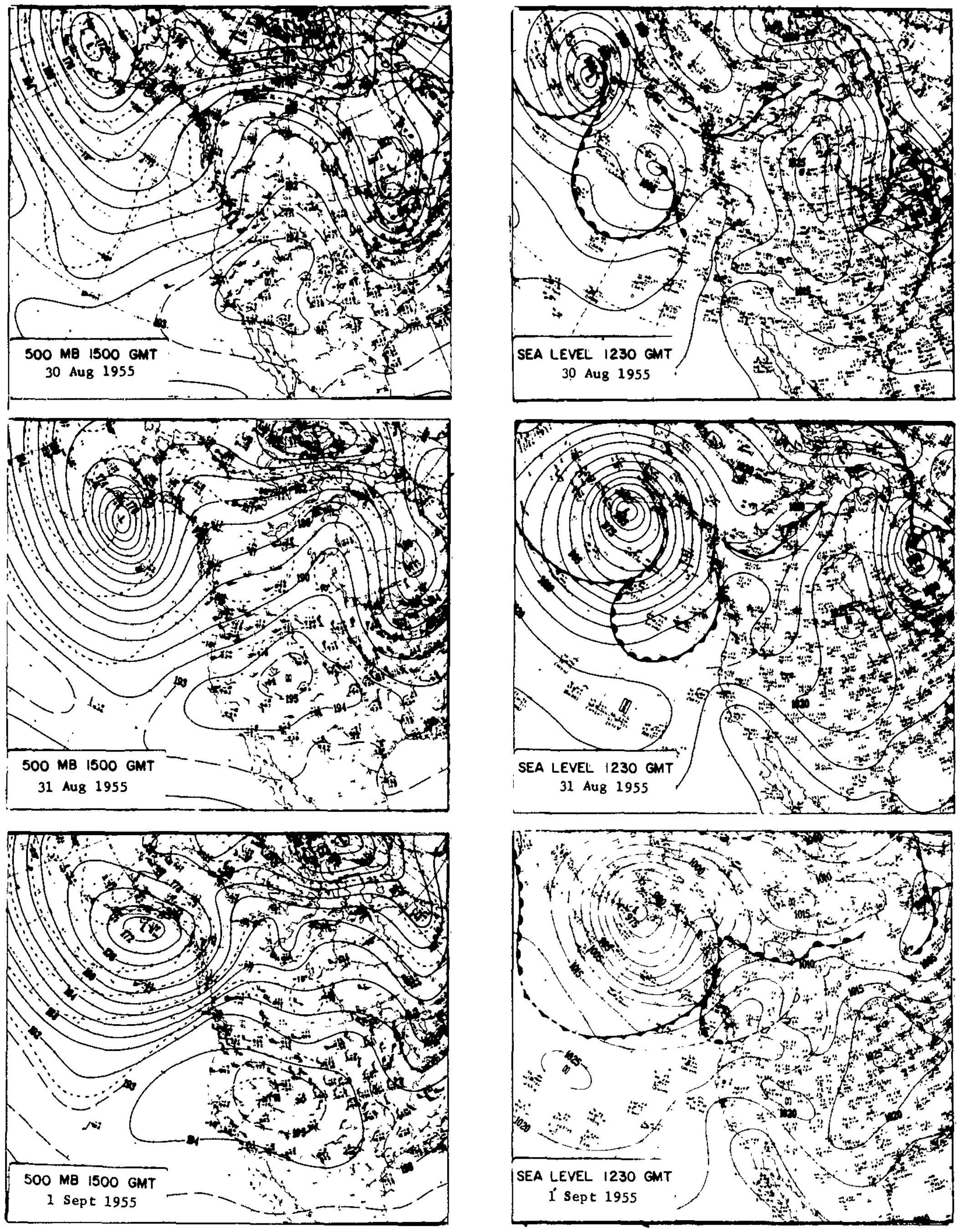


Figure 76. --Surface and 500 mb charts, August 30-September 7, 1955, illustrating a Subtropical High Aloft pattern.

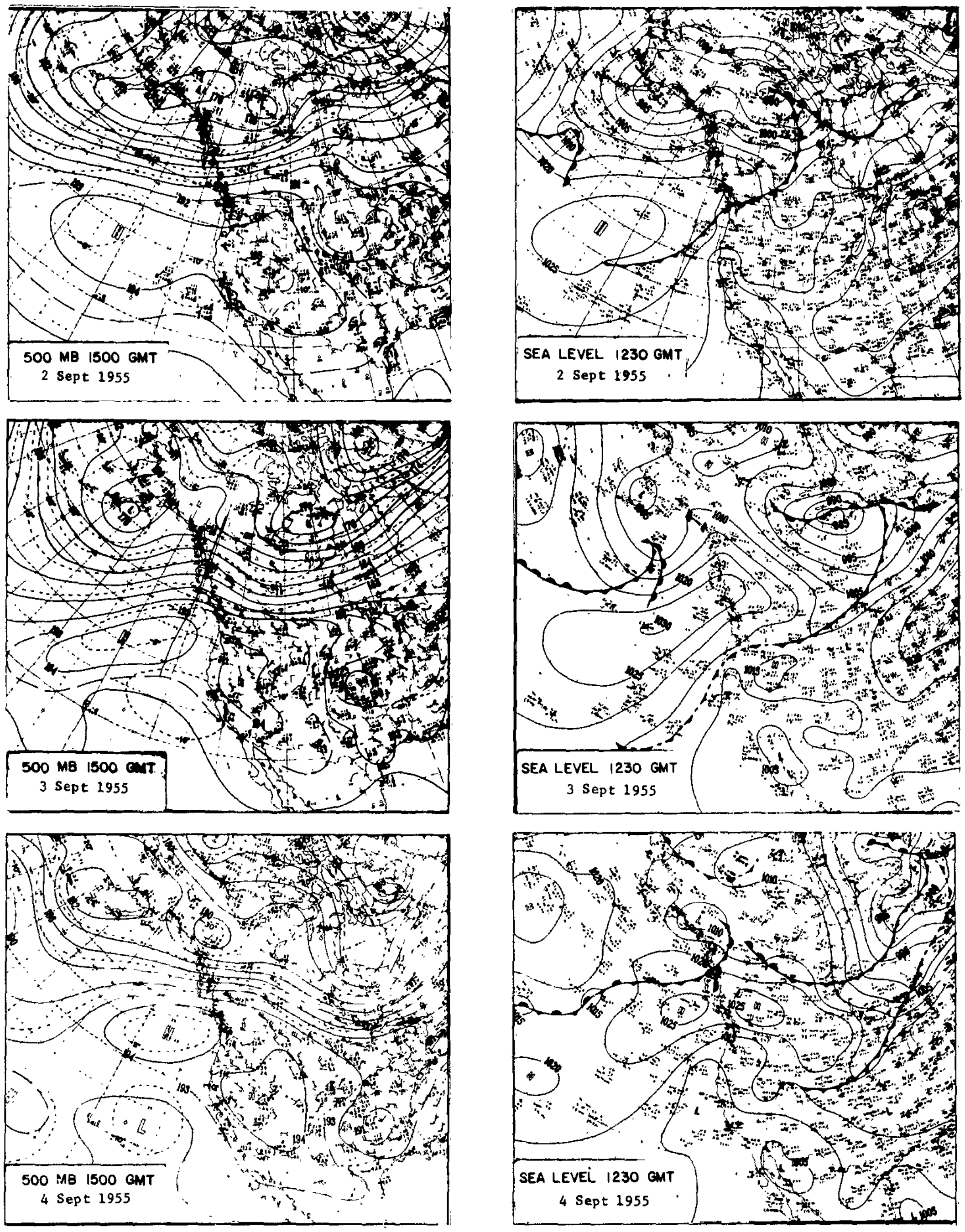


Figure 76. --Continued.

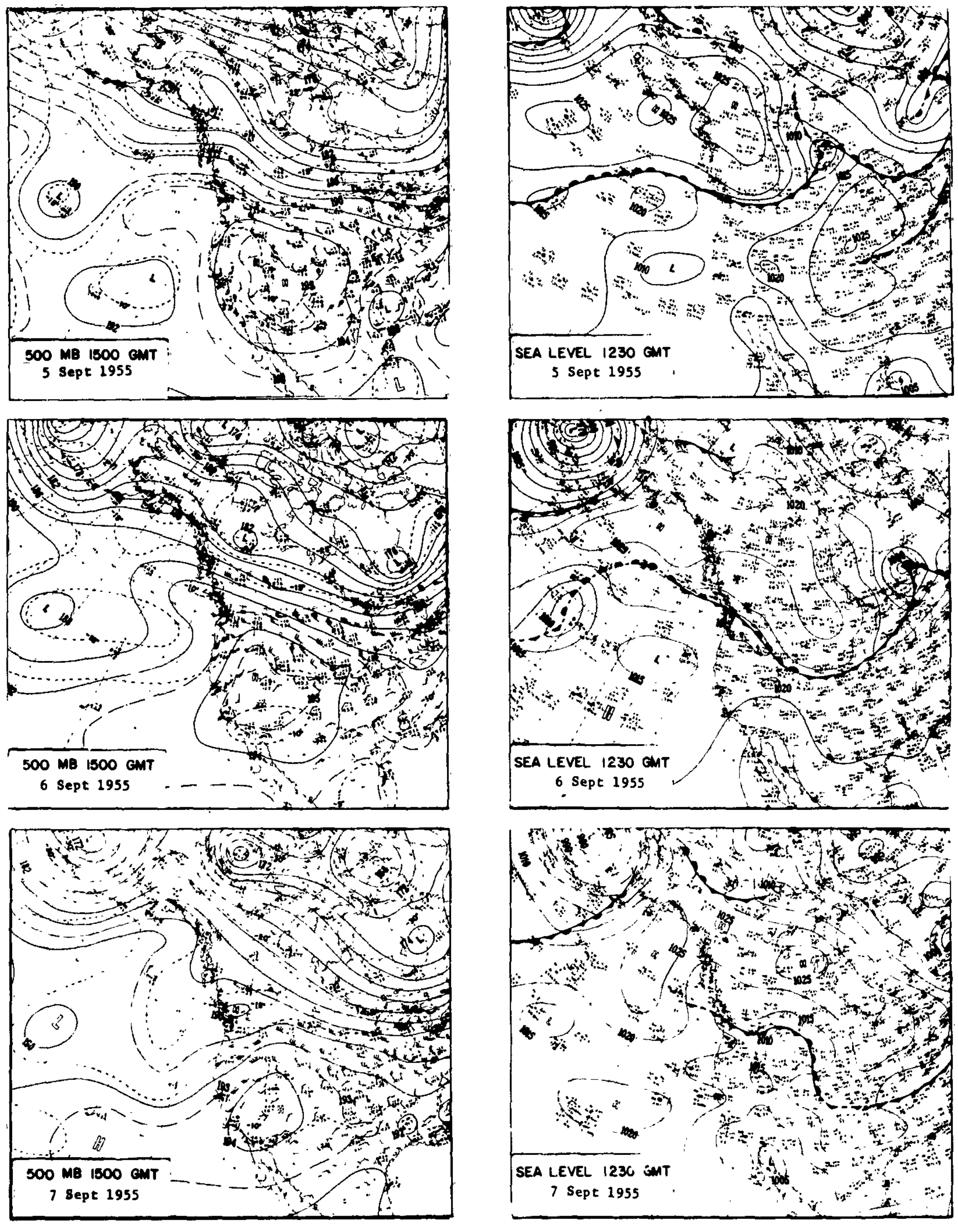


Figure 76. --Continued.

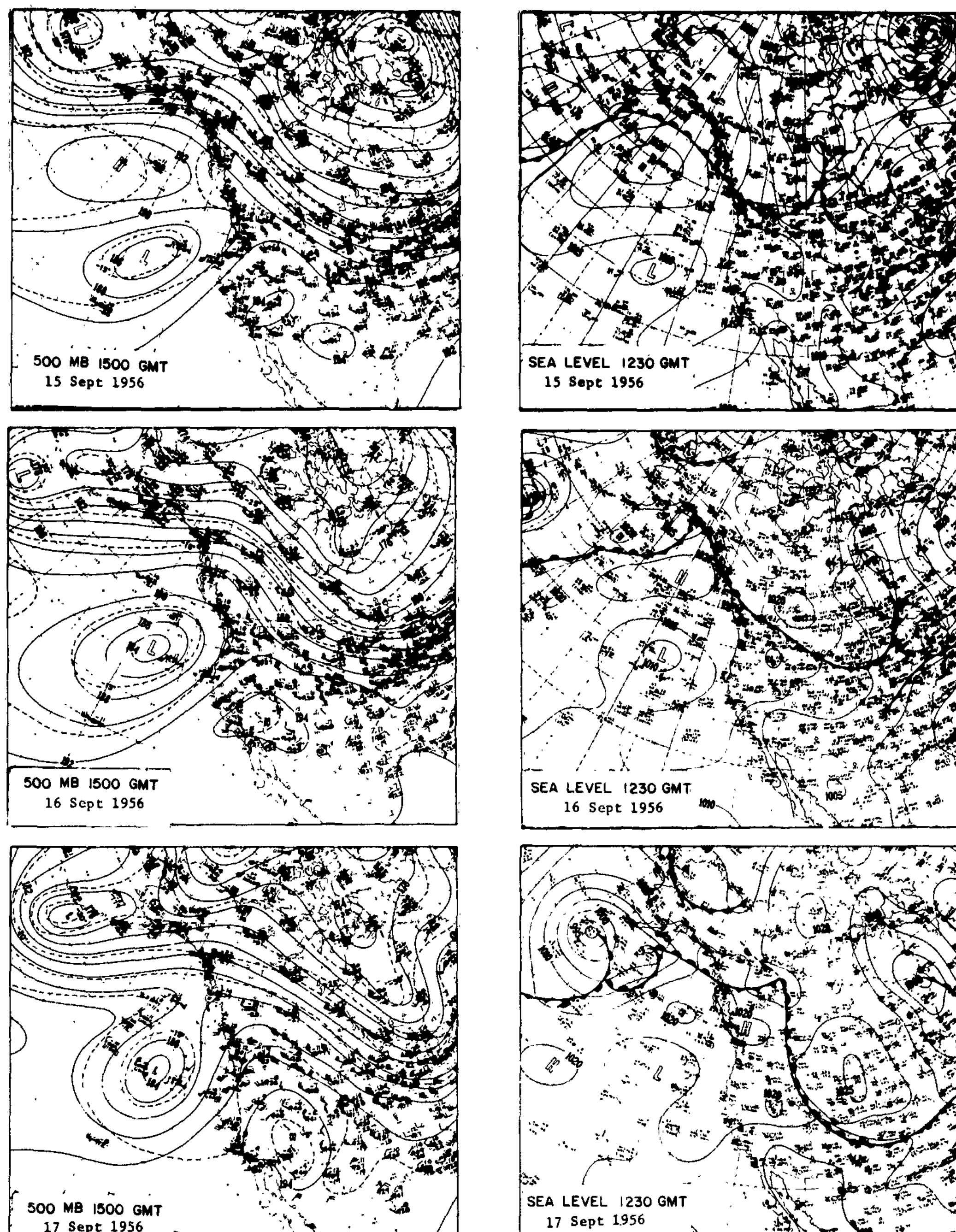


Figure 77. --Surface and 500 mb charts, September 15-19, 1956, illustrating high fire danger with southwest flow aloft.

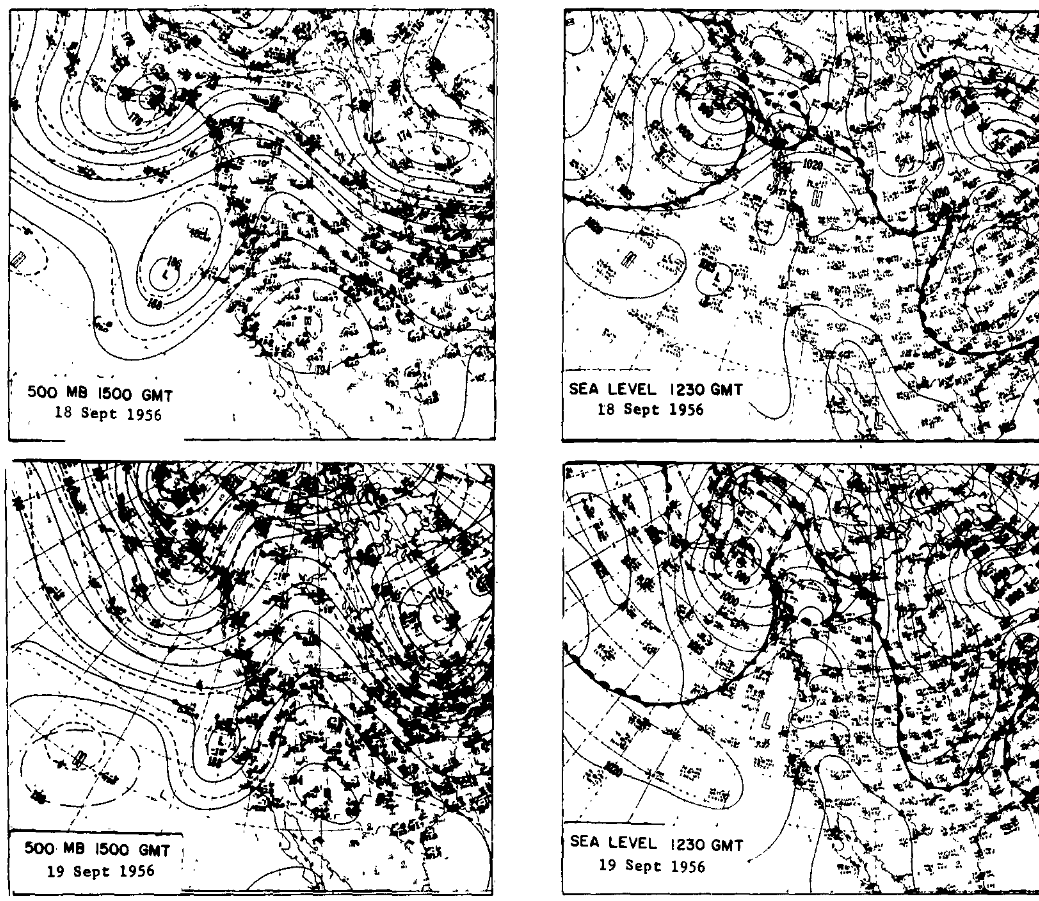


Figure 77. --Continued.

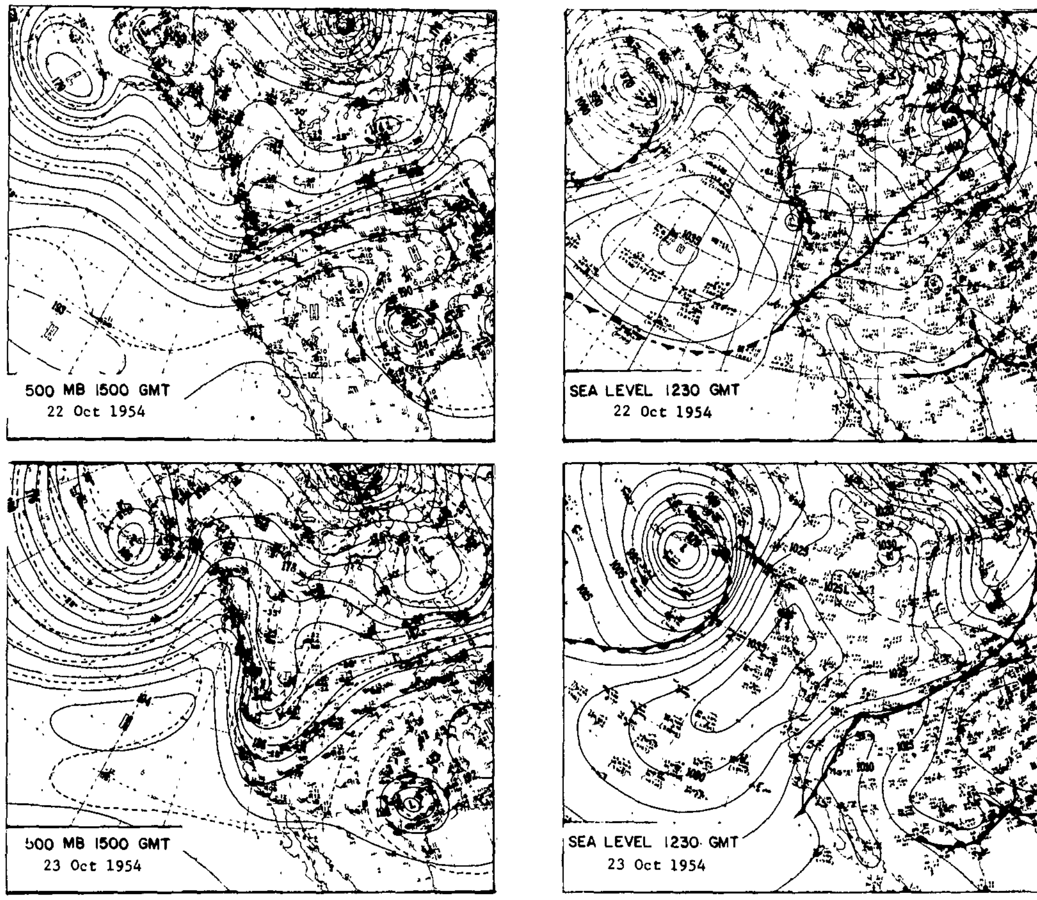


Figure 78. --Surface and 500 mb charts, October 22-25, 1954, illustrating post-frontal high fire danger.

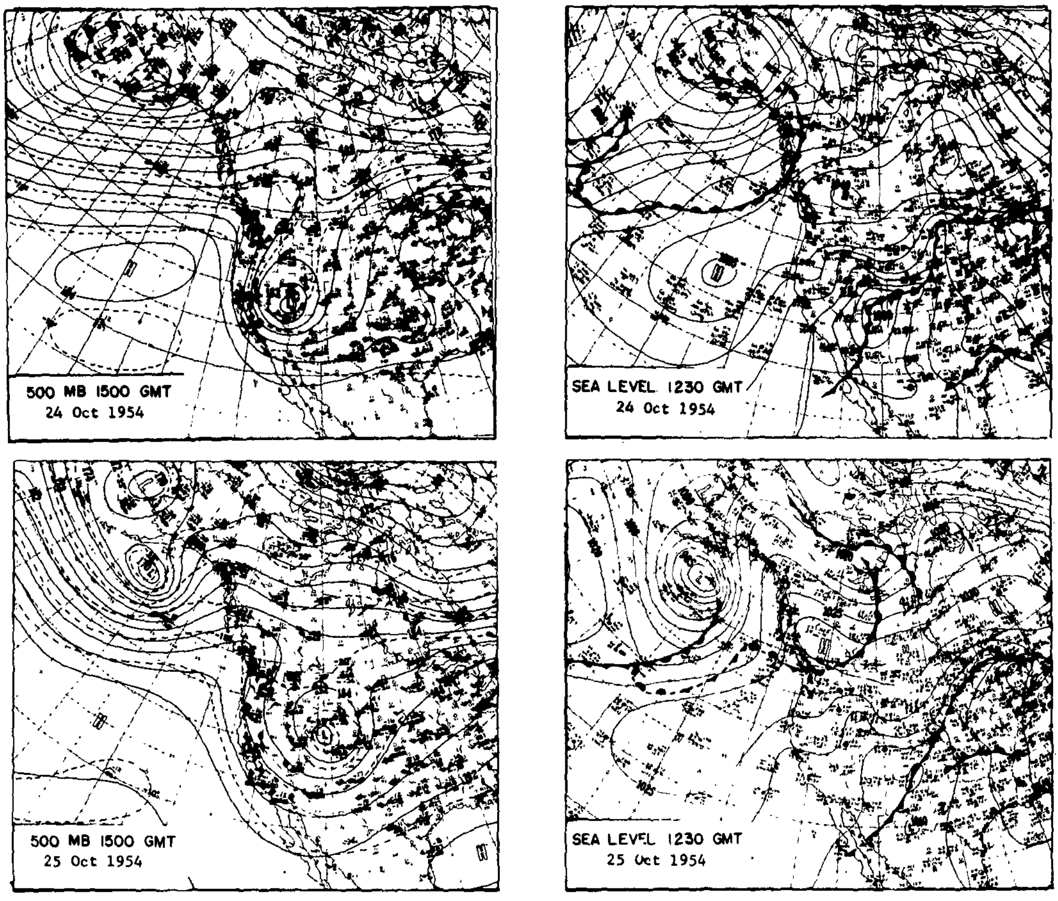


Figure 78. --Continued.

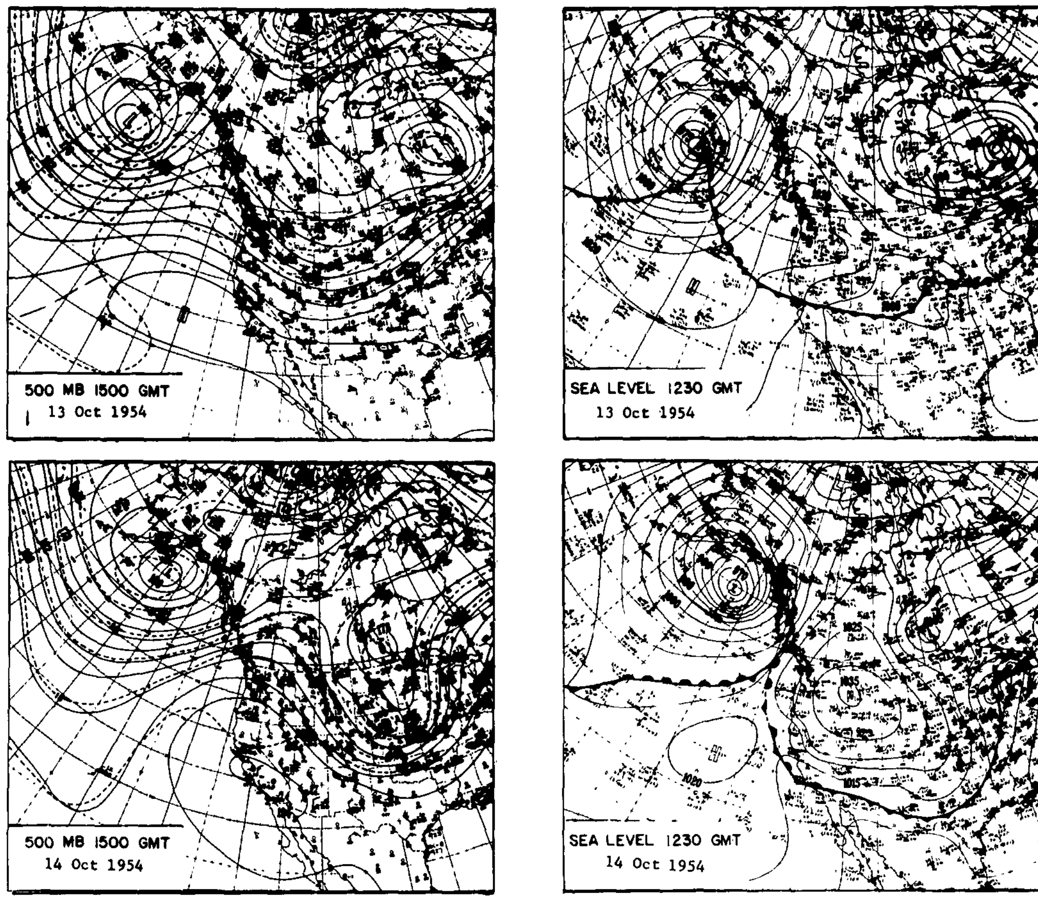


Figure 79. --Surface and 500 mb charts, October 13-16, 1954, illustrating the Great Basin High type.

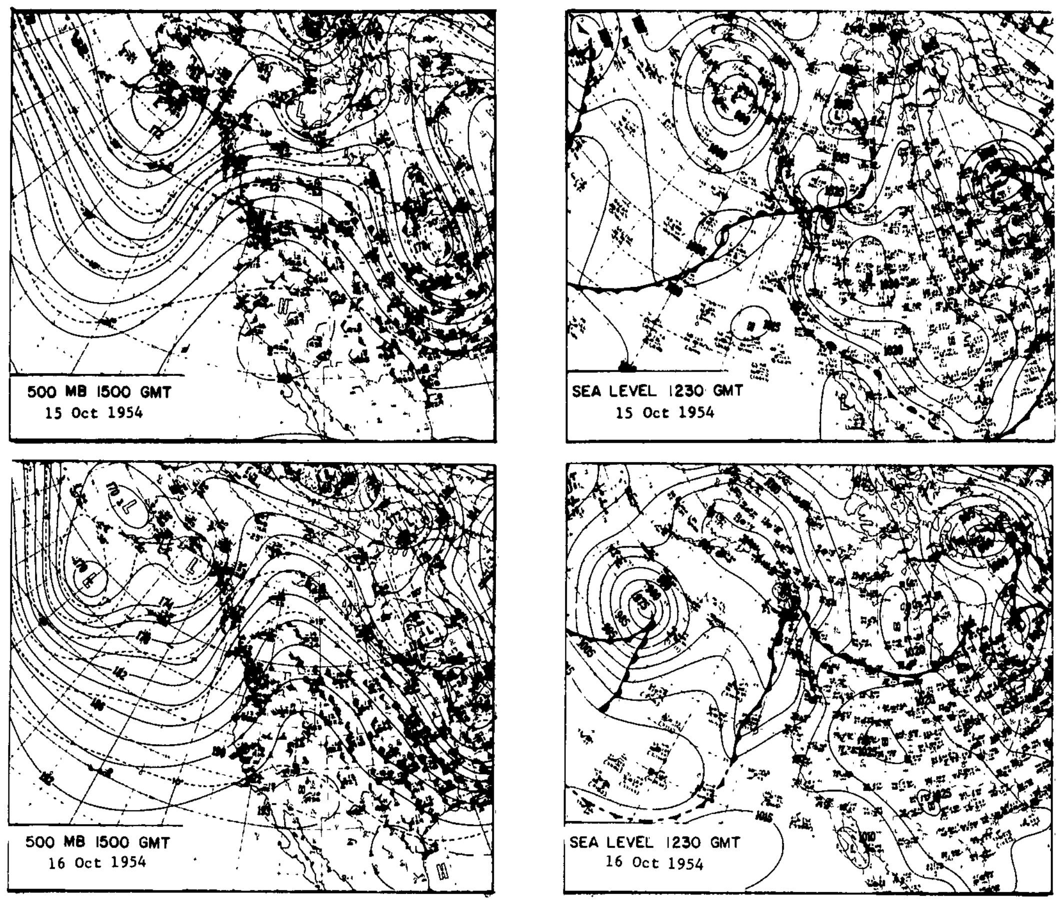


Figure 79. --Continued.

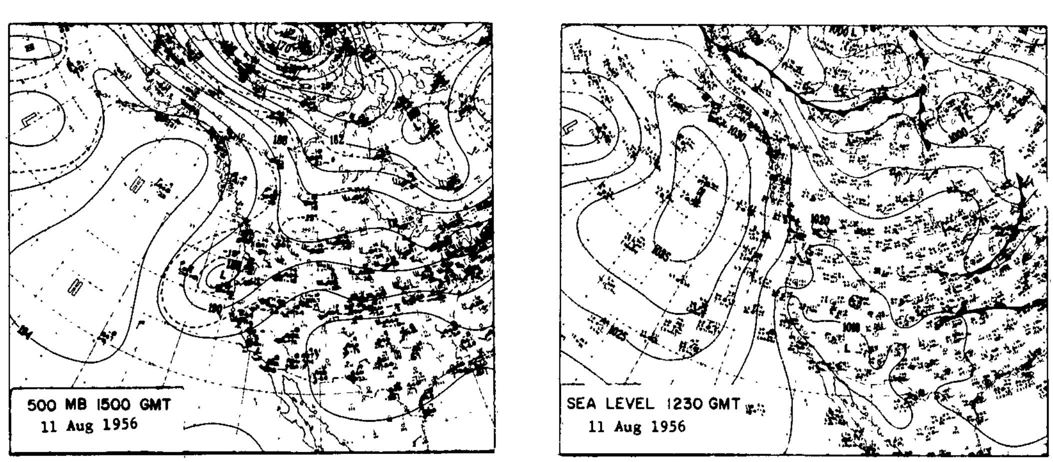
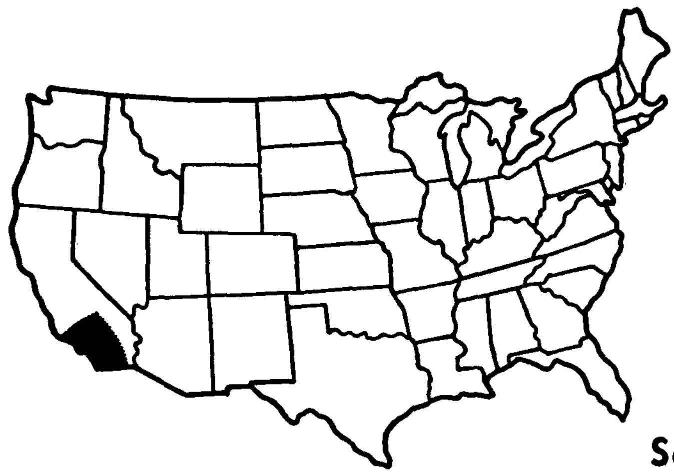


Figure 80. --Surface and 500 mb charts, August 11, 1956.



Southern California Region

The Southern California region includes the area from the Tehachapi and Sierra Madre Mountains southward to the Mexican border and from the coast to the desert. The weather stations at Los Angeles Airport and Sandberg were used to represent this area. Topography and the proximity of the Pacific Ocean bring southern California a complex climate. Coastal areas are affected by marine air, frequently accompanied by stratus, moving in from the ocean. The extent to which marine air penetrates inland depends upon the synoptic pressure pattern. Offshore flow may prevent marine air from crossing the coastline. At times it may influence only the coastal strip, brought in primarily by the sea breeze. If the marine layer is deep because of a trough of low pressure aloft, the cool, humid air may reach to the mountains and even flow through the passes to the east and north.

The southern California summer season is dry, nearly all of the rain falls in the months from September through May. These rains are caused by storms which move in from the Pacific. The summertime precipitation that does occur is confined usually to the mountain areas and falls in thundershowers. Moisture for these showers comes from the Gulf of Mexico by way of New Mexico, Arizona, and northern Mexico, or from dying tropical storms moving northward off the coast of Baja California. Average annual rainfall varies from less than 15 inches along the coast to more than 40 inches in some of the higher mountain areas.

Except during unusually wet years, the fire season in southern California lasts year round. Inland, the peak of the season is during the summer and early fall, with a secondary peak in March. Along the coast, marine air is dominant in the summer. Consequently, the highest fire danger there occurs during the fall and early winter and a secondary peak in late winter or early spring. Offshore flow is the cause of high fire danger along the coast.

A check on the frequency of C, D, and E fires on the four National Forests in southern California shows that the large-fire occurrence follows the seasonal changes in fire load index (fig. 81). The great majority of fires occur during the summer and early fall and a secondary peak appears in March.

Fire load indexes at Sandberg and Los Angeles (tables 50 and 51) show the seasonal difference between inland mountains and the coastal basin. Los Angeles rarely has a day with fire load index higher than 22 during the summer months. Sandberg, which represents higher elevations in the region, has peak occurrence during these months. The coastal areas will not have high fire danger unless pressure builds up inland and creates an offshore gradient. This rarely occurs in the summertime because of the normal pattern of lower pressures over the continents. In fall, winter, and early spring, offshore gradients appear frequently.

The general level of fire danger in southern California is considerably higher at higher elevations and inland areas than it is near the coast. Sandberg had a fire load index of 22 or higher about 37 percent of the days year-round, while Los Angeles had 22 or higher less than 3 percent of the days. At Sandberg more than 11 percent of the days had 50 or higher.

Practically all of the high fire danger cases found during the 10-year study period could be grouped into four principal synoptic patterns and types. These are:

1. Subtropical High Aloft

2. Meridional Ridge - Southwest Flow Pattern

3. Pacific High - Post-frontal Type

4. Santa Ana Type

The Subtropical High Aloft Pattern

A Subtropical High Aloft results in high temperatures and low humidities in Southern California just as it does for Northern and Central California. Since this pattern is fully discussed for the latter region, and the example given in the discussion produced a period of critical fire weather in Southern California also, it will not be treated in detail here.

This pattern creates a very serious fire weather-situation in California during the summer and early fall months. It is sometimes referred to as a "heat wave" type because of the very high temperatures it produces. In the example discussed in the Northern and Central California region (fig. 76), record high temperatures were also recorded at many stations in southern California. Burbank had 111°F September 5 and 6, 1955--a new high for September.

Table 50.--Number of days with fire load index 22 and above at Sandberg, by months, Southern California region 1951-60.

	1951			1952			1953			1954			1955			1956			1957			1958			1959			1960			Total		
	Fire load index equal to or greater than--																																
Month	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50
Jan.	7	4	2	0	0	0	1	0	0	3	1	0	0	0	0	1	0	0	1	0	0	0	0	0	1	1	1	0	0	0	14	6	3
Feb.	7	3	2	1	0	0	4	0	0	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	21	3	2
Mar.	17	14	11	0	0	0	10	6	1	1	0	0	3	1	1	6	0	0	2	0	0	0	0	0	6	0	0	2	0	0	47	21	13
Apr.	9	6	4	3	0	0	1	0	0	5	1	0	6	0	0	1	0	0	0	0	0	0	0	0	6	1	0	2	2	1	33	10	5
May	14	12	6	13	2	0	2	0	0	13	3	1	6	3	0	1	0	0	0	0	0	5	0	0	0	0	0	5	0	0	59	20	7
June	19	13	6	6	4	4	11	5	2	15	11	6	15	5	0	12	4	3	16	6	3	11	4	3	18	7	6	22	14	5	145	73	38
July	26	20	16	23	15	7	27	18	9	24	17	12	20	0	0	18	11	4	29	16	6	14	4	2	25	17	10	24	14	7	230	132	73
Aug.	25	22	19	27	19	11	20	16	13	23	9	4	25	16	9	18	10	8	25	12	4	25	6	4	22	19	10	23	17	9	233	146	91
Sept.	27	20	13	22	16	10	24	18	9	20	16	15	20	16	12	26	18	11	17	3	1	21	11	7	12	6	2	20	10	6	209	134	86
Oct.	20	13	7	23	14	7	16	12	4	22	12	6	21	14	8	10	5	1	2	1	0	18	9	6	14	9	6	15	3	0	161	92	45
Nov.	12	8	6	5	2	1	8	2	1	13	8	3	12	5	2	24	13	12	10	6	4	11	5	0	20	11	6	5	2	0	120	62	35
Dec.	0	0	0	3	0	0	7	2	0	7	4	1	0	0	0	19	8	2	8	3	2	18	6	1	8	5	1	5	2	0	75	30	7
Total	183	135	92	126	72	40	131	79	39	153	82	48	128	60	32	136	69	41	110	47	20	123	45	23	132	76	42	125	64	28	1347	729	405

Table 51.--Number of days with fire load index 22 and above at Los Angeles, by months, Southern California region, 1951-60.

	1951			1952			1953			1954			1955			1956			1957			1958			1959			1960			Total		
	Fire load index equal to or greater than--																																
Month	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50	22	37	50
Jan.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	2	0	0	3	0	0
Feb.	0	0	0	0	0	0	6	2	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	2	0
Mar.	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0	5	0	0
Apr.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
May	0	0	0	0	0	0	3	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	1	1
June	0	0	0	0	0	0	3	1	1	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	5	3	1
July	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Aug.	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Sept.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	0
Oct.	3	1	0	0	0	0	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	6	2	0	1	0	0	2	1	0	15	5	0
Nov.	2	1	0	1	0	0	3	1	0	2	0	0	1	0	0	10	2	0	0	0	0	5	2	0	6	2	1	0	0	0	30	8	1
Dec.	1	0	0	0	0	0	3	2	0	1	0	0	0	0	0	4	2	1	1	0	0	5	3	0	6	0	0	0	0	0	21	7	1
Total	6	2	0	1	0	0	22	8	2	3	0	0	5	0	0	16	4	1	3	2	0	18	8	0	15	2	1	4	1	0	93	27	4
Total for each year for both Sandberg and Los Angeles:	189	137	92	127	72	40	153	87	41	156	82	48	133	60	32	152	73	42	113	49	20	141	53	23	147	78	43	129	65	28	1440	756	409

Table 52.--Number of cases with fire load index 22 and above with Subtropical High Aloft, Southern California region, 1951-60

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Frequency	0	1	0	6	5	29	39	38	33	21	2	0	174
Total days	0	2	0	8	18	93	210	234	160	76	2	0	803
Range (days)	0	0	0	1-2	1-9	1-9	1-21	1-17	1-17	1-9	0	0	1-21
Average (days)	0	2.0	0	1.3	3.6	3.2	5.4	6.2	5.0	3.6	1.0	0	4.6

Los Angeles Airport had 108°F September 1--a new absolute highest temperature. Los Angeles City had 110°F--a new absolute highest, and September 1955 had the second highest average maximum for that month.

The subtropical High usually builds or moves westward across the south portion of the United States and the Southwest region. If affects the fire weather in southern California before it affects the regions farther to the north. Reports from higher elevation fire-weather stations in the eastern part of the Southern California region give an indication that the High is moving westward when their winds become southeasterly.

Extreme atmospheric instability through a deep layer will frequently accompany this weather pattern. Intense heating at the surface sometimes produces a lapse rate approaching the dry adiabatic rate from the surface to the 500 mb level and makes it easy for fires to develop convection columns of 20,000 to 25,000 feet and higher. The pattern is most frequent in July and August, and nearly as frequent in June and September (table 52).

The Meridional Ridge - Southwest Flow Pattern

The Southwest Flow pattern also was discussed in detail for the Northern and Central California region. In the Southern California region this pattern affects only the higher elevations just as it does farther north. Marine air keeps the fire danger low in coastal areas.

The air moving into Southern California is initially quite stable because of its passage over the cool water. It does not become unstable until it reaches the lee side of the mountain ranges where surface heating is more intense.

The fire danger decreases when the trough aloft moves closer to the coast and ceases in most areas when the marine layer becomes deep and penetrates some distance inland.

The Southwest Flow pattern occurs infrequently, averaging about two cases of high fire danger per year (table 53). Most of the occurrences were in summer and fall, and a few in spring.

Table 53.--Number of cases with fire load index 22 and above with Meridional Ridge - Southwest Flow Pattern, Southern California region, 1951-60

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Frequency	0	0	0	1	2	1	6	1	3	2	2	0	18
Total days	0	0	0	2	2	1	14	4	10	5	2	0	40
Range (days)	0	0	0	0	0	0	1-5	0	3-4	2-3	0	0	1-5
Average (days)	0	0	0	2.0	1.0	1.0	2.3	4.0	3.3	2.5	1.0	0	2.2

The Pacific High - Post-frontal Type

After the passage of a dry cold front, a portion of the Pacific high pressure cell may move inland north of the Southern California region so that winds in the post-frontal area become northerly or northeasterly, and fire danger becomes high. The front itself may be very weak--often only the trailing end of a front passing through to the north.

The flow pattern aloft may be meridional, zonal, block, or short-wave train. The long-wave ridge position is usually over the eastern Pacific, and the trough in the western United States. A short wave aloft, associated with the surface system, moves through the long-wave pattern. The ridge portion of the short wave is strong enough to allow a portion of the Pacific High at the surface to move inland.

The strongest winds in the post-frontal area are associated with the meridional or short-wave train pattern and with the 500 mb jet stream over the region. Winds aloft with these patterns shift into the north and lend support to the surface winds. The zonal pattern is less effective in reinforcing surface winds. However, in southern California, because some of the mountain ranges and part of the coastline are oriented east-west, the surface winds can be offshore and downslope when their direction is anything from northwest around through north to east. Therefore the zonal pattern can be more effective in increasing fire danger in this region than in Northern and Central California.

The important factors creating critical burning conditions in the post-frontal area are:

1. Strong winds resulting from a steep pressure gradient between the front and the nose of the Pacific High.

2. Air flowing from higher to lower elevations, producing the characteristic warming and drying of the foehn effect. (The temperatures may actually rise after the cold front passage because of compressional heating.)

3. Instability behind the cold front due to cooling aloft with the short-wave trough and the warming at the surface as the air moves over warmer land.

4. Lack of precipitation as the trailing ends of cold fronts pass.

The post-frontal type accounted for about 8 percent of the cases of high fire danger in this region. Of these, about 34 percent were associated with a zonal pattern aloft, 18 percent with a block, 32 percent with a short-wave train, and 16 percent with a meridional pattern. The type is most frequent in May, June, and September (table 54). Many frontal passages occur during the winter season but these are likely to be accompanied by precipitation. If so, they will not produce high fire danger.

The period of high fire danger usually lasts 1 to 2 days with this type. Sometimes it does not develop until the day after the frontal passage because the pressure gradient does not increase until the High builds inland. During long periods of high fire danger, up to 9 days in some cases, a succession of fronts pass with only a brief lowering of the fire danger between them.

Table 54.--Number of cases with fire load index (22 and above) associated with the Pacific High - Post-frontal type, Southern California region, 1951-60

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Frequency	2	0	1	5	13	14	4	0	10	4	2	1	56
Total days	2	0	1	5	25	36	6	0	12	8	2	1	98
Range (days)	0	0	0	0	1-4	1-9	1-2	0	1-3	1-3	0	0	1-9
Average (days)	1.0	0	1.0	1.0	1.9	2.6	1.5	0	1.2	2.0	1.0	1.0	1.8

When a large portion of the Pacific High breaks off and settles into the Great Basin, or a High from northwest Canada is pulled down into the Great Basin behind a cold front, the Santa Ana type follows the post-frontal type.

The fire danger decreases in the Pacific High-Post-frontal type when the pressure gradient in the post-frontal area decrease and the winds diminish. Such a decrease in fire danger may be only temporary if another front is on the way. More lasting relief comes when the flow pattern aloft changes to the more normal light southwesterly flow.

The period June 27-30, 1955 (fig. 82) illustrates the post-frontal type. June 30 a frontal system accompanied by a strong short-wave trough aloft was approaching the coast. The short-wave ridge following was significant as indicated by the 60-knot northwesterly wind at ship Papa. The next day the trough crossed the coast. The cold front moved inland and the lower portion passed through northern and central California. A nose of the Pacific High entered British Columbia and the Pacific Northwest and followed the front southeastward.

The fire load index at Sandberg jumped to 39 June 29 after the cold front passed. The isobars to the rear of the front became oriented north-northeast to south-southwest, and the pressure gradient in this area increased. Strong northwest winds behind the trough aloft gave support to the surface flow.

On June 30 the gradient both at the surface and aloft decreased and the fire danger dropped below critical levels.

The Santa Ana Type

A foehn wind known in southern California as the Santa Ana produces some of the most critical fire weather conditions known. Humidities are frequently less than 5 percent, sometimes down to 1 percent. Wind speeds may be 50 to 60 mph, with gusts occasionally to 100 mph. Temperatures at times may be quite low in the initial stages of a Santa Ana, but usually at low elevations the temperatures are mild. Santa Ana winds develop during the fall and winter, frequently before much rain has fallen after the dry summer season, at a time of the year when the moisture content of living brush fuels is low. All of these factors add up to explosive burning conditions.

The synoptic pattern which produces the Santa Ana is the Great Basin High, but we are calling it the Santa Ana type because it is widely known as such in this region. The type develops when a cold front, accompanied by a vigorous short-wave trough aloft, passes through California and is followed by either a Pacific or Northwest Canadian High which settles into the Great Basin. When pressure builds up in the Great Basin, the thermal trough that usually extends from southeastern California up through the Central Valley is forced off the California coast. A strong northeast to southwest pressure gradient is established over southern California. The southwestward flowing air is forced across the mountain ranges and flows down the leeward side to sea level, warming and drying as it does so. Whether the air that reaches the California coast comes from the surface in the Great Basin, where the average elevation is about 5,000 feet, or from aloft over the Great

Basin, is not definitely known. When the relative humidity is extremely low, it can be assumed that the air originated at high levels over the Great Basin, where broadscale subsidence occurs above the surface High.

The upper-air pattern with the Santa Ana type is usually meridional, with the ridge off the coast and the trough in the western states, preferably the Southwest. The northwest flow is favorable for steering a surface High into the Great Basin following a short-wave trough. The short-wave trough deepens as it reaches the long-wave trough position in the Southwest and frequently forms a closed Low. The resulting increased northerly, sometimes northeasterly, flow over southern California seems to strengthen the northeasterly surface wind. About half of the Santa Anas have a meridional pattern aloft.

Block patterns and short-wave trains are also found with Santa Anas. Each occurs with about one-quarter of the cases. The ridge and trough positions are in the same relative positions when the High moves into the Great Basin as they are with the meridional pattern. The zonal pattern is rare with the Santa Ana type, although it does occur.

The surface High that moves into the Great Basin is usually of Pacific origin. It is a breakoff of the east Pacific anticyclone and at times may be the major portion of it. Occasionally with a strong meridional flow pattern, a High from Northwest Canada is steered into the Great Basin. This continental air is colder and more dense than the Pacific air masses. The greater density difference established between the Great Basin and the California coast results in a more severe type of Santa Ana wind, and one that is more likely to surface on the lee side of the mountains.

Santa Ana winds can be classified as two types: a warm type and a cold type. The warm-type Santa Ana affects only the higher elevations--the mountain peaks, ridges, and passes. On the leeward side, the Santa Ana wind remains aloft and does not reach down to the surface. The cold-type Santa Ana, however, flows down the lee slopes, scours out the canyons, and fans out onto the plain. Fires occurring in the foothills are driven out into the populated areas. The difference between the two may be relative coldness of the air mass in the Great Basin. The colder and more dense this air is, the more likely it is to follow the topography in flowing down the lee slopes. This aspect of Santa Ana winds is not fully understood as yet, and the mountain wave phenomenon may also be a factor.

Santa Ana winds may change from one type to another during the same case. When the Santa Ana first sets in it may be a cold type, surfacing on the lee side of the mountains for the first day or two and affecting all elevations. Then as the High in the Great Basin begins to warm, the surfacing becomes intermittent. Later in the period, the Santa Ana becomes a warm type and the Santa Ana winds stay aloft. At the surface on the lee side, the mountain-valley and land-sea breeze regimes are dominant although the entire area is covered with very dry, mild air.

Table 55.--Number of Santa Ana cases by months, Southern California region, 1951-60

Item	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Frequency	7	10	17	8	7	4	1/2	0	11	19	26	18	129
Total days	12	19	43	15	10	18	1/5	0	48	86	128	66	450
Range (days)	1-3	1-7	1-9	1-6	1-2	1-8	1-4	0	1-7	3-8	1-12	1-10	1-12
Average (days)	1.7	1.9	2.5	1.8	1.4	4.5	2.5	0	4.4	4.5	5.0	3.7	3.5

1/ Cases affecting high elevations only.

The Santa Ana type is a fall, winter, and early spring phenomenon. The maximum occurrence is in November and a secondary maximum appears in March (table 55).

The duration of a Santa Ana period may run from 1 to as long as 12 days. The longer periods, however, are usually due to two or even three Highs moving into the Great Basin without a real break in the fire danger.

The high fire danger in a Santa Ana situation ends when the pressure gradient decreases and the winds diminish. This happens either when the Great Basin High moves eastward or when the intensity of the High decreases as the air mass is warmed. As the offshore pressure gradient decreases, the sea breeze works marine air farther and farther inland, and finally covers the coastal plains and the foothills. Even then a critical situation may be encountered. A delicate balance is set up between the offshore gradient and the sea breeze. When the sea breeze force becomes great enough, the sea breeze front moves in with a rush. It brings strong westerly winds at a time when fuel moistures are still low. Only after the humidity rises and the temperature drops is the fire danger relieved.

In predicting the onset of a Santa Ana wind, the possibility of a cold surface High moving into the Great Basin is the important factor. The steering pattern aloft must be favorable. The parameters used in an objective aid at the Weather Bureau in Los Angeles are: the height difference at 500 mb from Ely, Nevada to Oakland, California, the temperature difference at 500 mb from Ely to Spokane, Washington, and the pressure difference at the surface from Ely to Medford, Oregon. The first parameter indicates the strength of the steering current. The second indicates the density difference--the possibility of cold air moving into the Great Basin. The third is an indication of the buildup of surface pressure in the Great Basin. As the High moves into the Great Basin, trends in the pressure gradient between Los Angeles and

Tonopah, Nevada, are useful as short range indicators. A pressure difference of 7 mb offshore is enough to begin northeasterly winds, and winds become strong with gradients of 11 to 12 mb if the Santa Ana is a cold type. With a warm-type Santa Ana, offshore gradients of as much as 15 mb have been observed to produce strong high-level winds, but did not result in low-level easterly winds.

An example of a Santa Ana type with a Pacific High (fig. 83) originated when a short-wave trough followed by strong northwesterly winds moved into the western states December 10, 1953. At the surface the associated cold front moved through California that day and a strong extension of the Pacific High nosed into the Pacific Northwest. December 11 the trough aloft deepened over New Mexico, and the winds over southern California became strong northerly. A 1035 mb Pacific High moved into the Great Basin and established an offshore gradient. The fire load index rose from 3 December 10 to 18 December 11 at Los Angeles, and from 0 to 35 at Sandberg.

The Great Basin High intensified to 1040 mb December 13. Sandberg's wind went to northeast 22, the humidity down to 15 percent, and the fire load index to 47. Critical conditions continued December 14: the temperature at Los Angeles rose to 84, the humidity dropped to 12 percent, and the fire load index rose to 24. The highest humidity was 32 percent. The winds at the Los Angeles Airport were not strong in this case, at least at the time of the 1400 P.s.t. observation. In fact, strong winds occur only infrequently at the Los Angeles Airport during Santa Ana situations.

December 15, as the Great Basin High weakened, the gradient over southern California diminished. The fire load index at Los Angeles dropped to 8, and at Sandberg to 15. Subsequently, conditions continued to improve and the fire load index dropped to 0 at Los Angeles December 17.

The second Santa Ana example (fig. 84) is a case in which a surface High from northwest Canada moved southward to the Great Basin, creating an offshore gradient in southern California. A meridional flow pattern covered the eastern Pacific December 6, 1956, and a vigorous short-wave trough aloft entered the Pacific coast. At the surface a complex frontal system had moved into the Great Basin; to the north, in southwest Canada, a 1030 mb High was moving southward. The fire load index at both Los Angeles and Sandberg was 0.

Strong north to northwest winds behind the trough aloft steered the High from Canada into the Great Basin December 7 and 8. Strong anticyclogenesis increased the pressure of the High to 1045 mb. The fire load index at Los Angeles jumped to 20 on December 7 in a post-frontal situation following the first of two surface cold fronts. The peak fire danger at both Los Angeles and Sandberg appeared December 9, when Los Angeles had 55 and Sandberg 39. The Great Basin High had grown to more than 1050 mb and a very strong offshore gradient covered all of

southern California. The 1400 P.s.t. relative humidity at Los Angeles dropped from December 6 through 9 as follows: 53 percent, 29 percent, 18 percent, and 7 percent.

The fire load index at Los Angeles dropped to 5 on December 10. Winds decreased and changed from a northerly direction December 9 to a westerly direction December 10, bringing in cooler and more humid air.

At Sandberg the fire danger remained high on December 10 as northeasterly winds continued and relative humidity dropped to 8 percent. The fire load index lowered to 0 on December 11 as the pressure gradient relaxed and humid air was brought into the region.

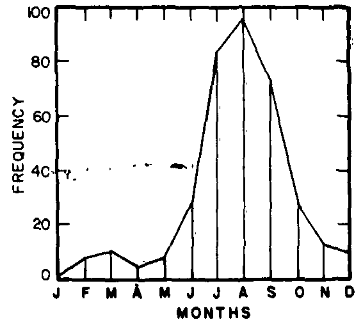


Figure 81. --Frequency of class C, D, and E fires on the four southern California national forests 1951-1960.

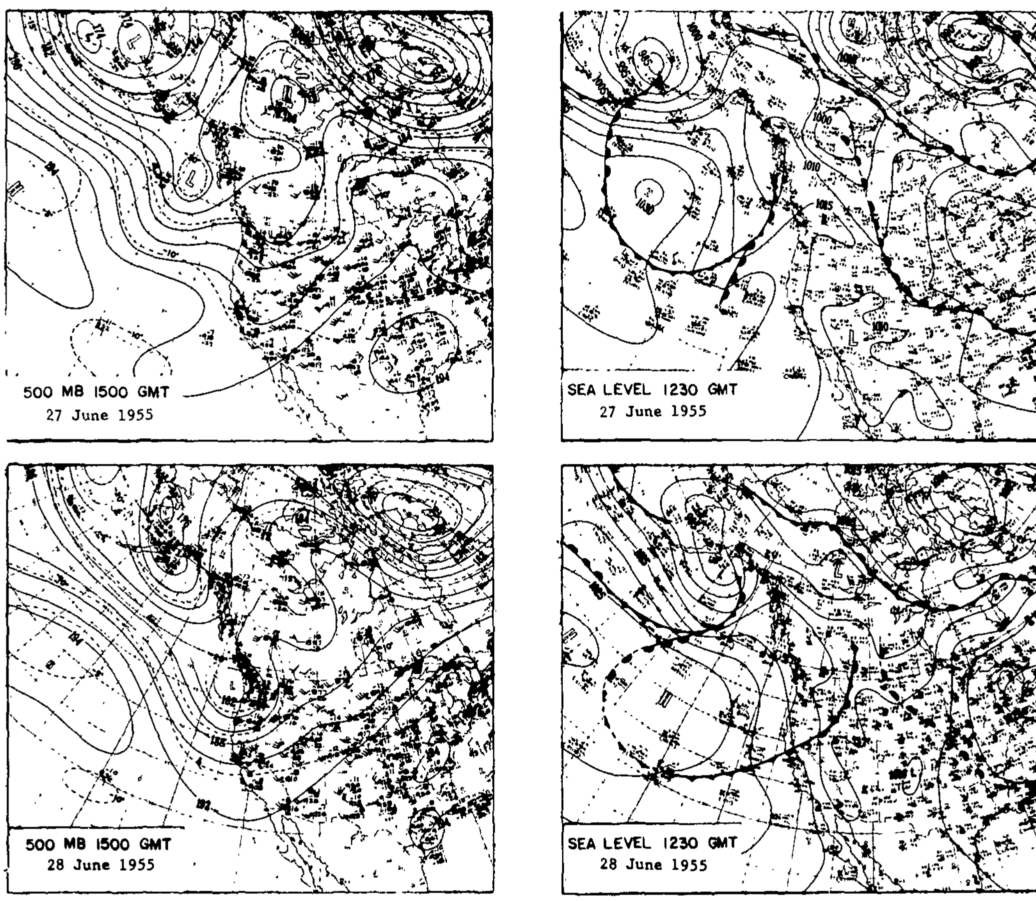


Figure 82. --Surface and 500 mb charts, June 27-30, 1955, illustrating post-frontal high fire danger. Sandberg had a fire load index of 39 on June 29.

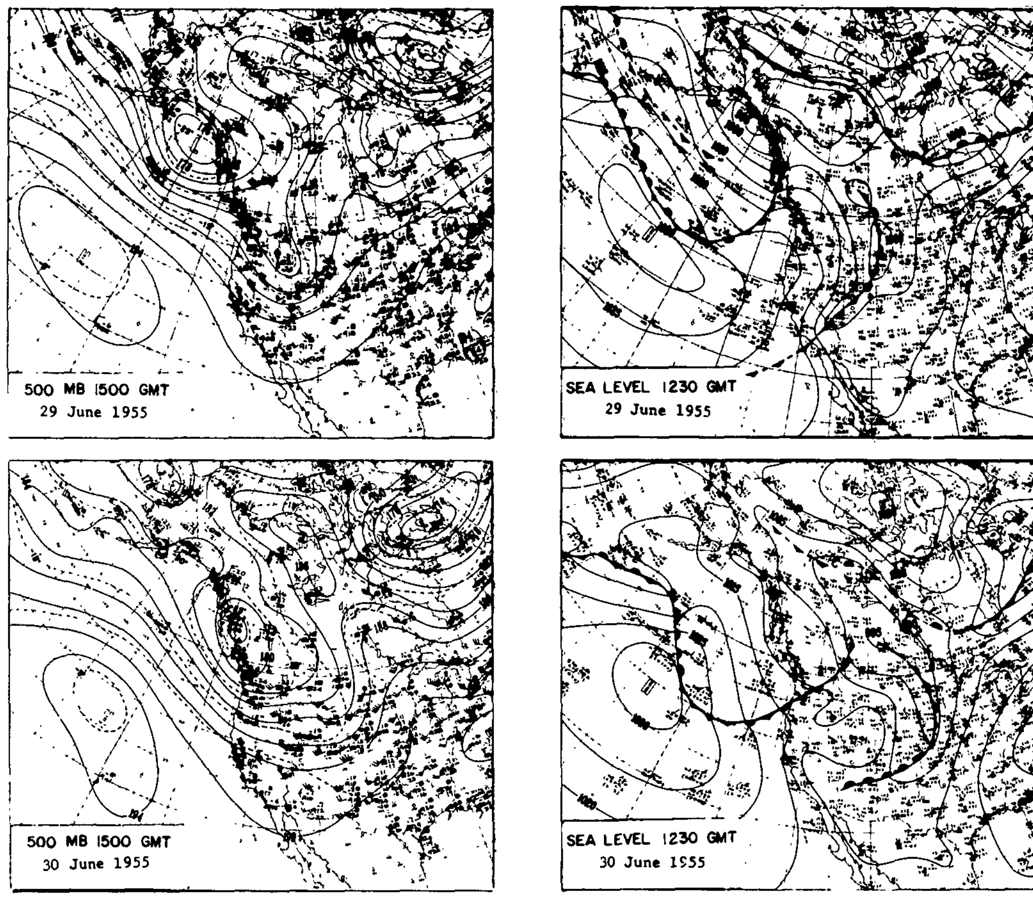


Figure 82. --Continued.

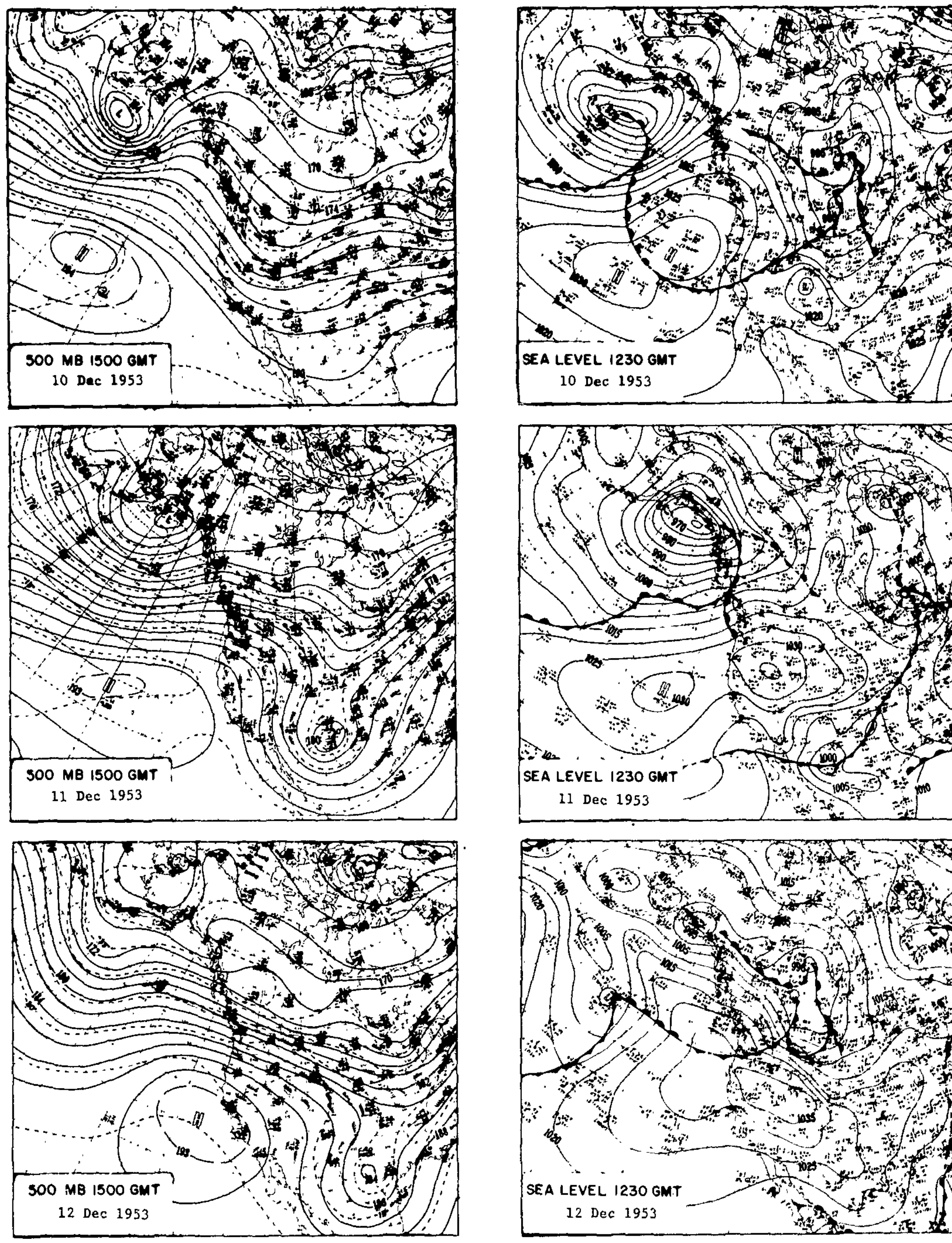


Figure 83. --Surface and 500 mb charts for December 10-15, 1953, illustrating a Santa Ana type with a Pacific High. The fire danger was high in southern California December 11 through 14.

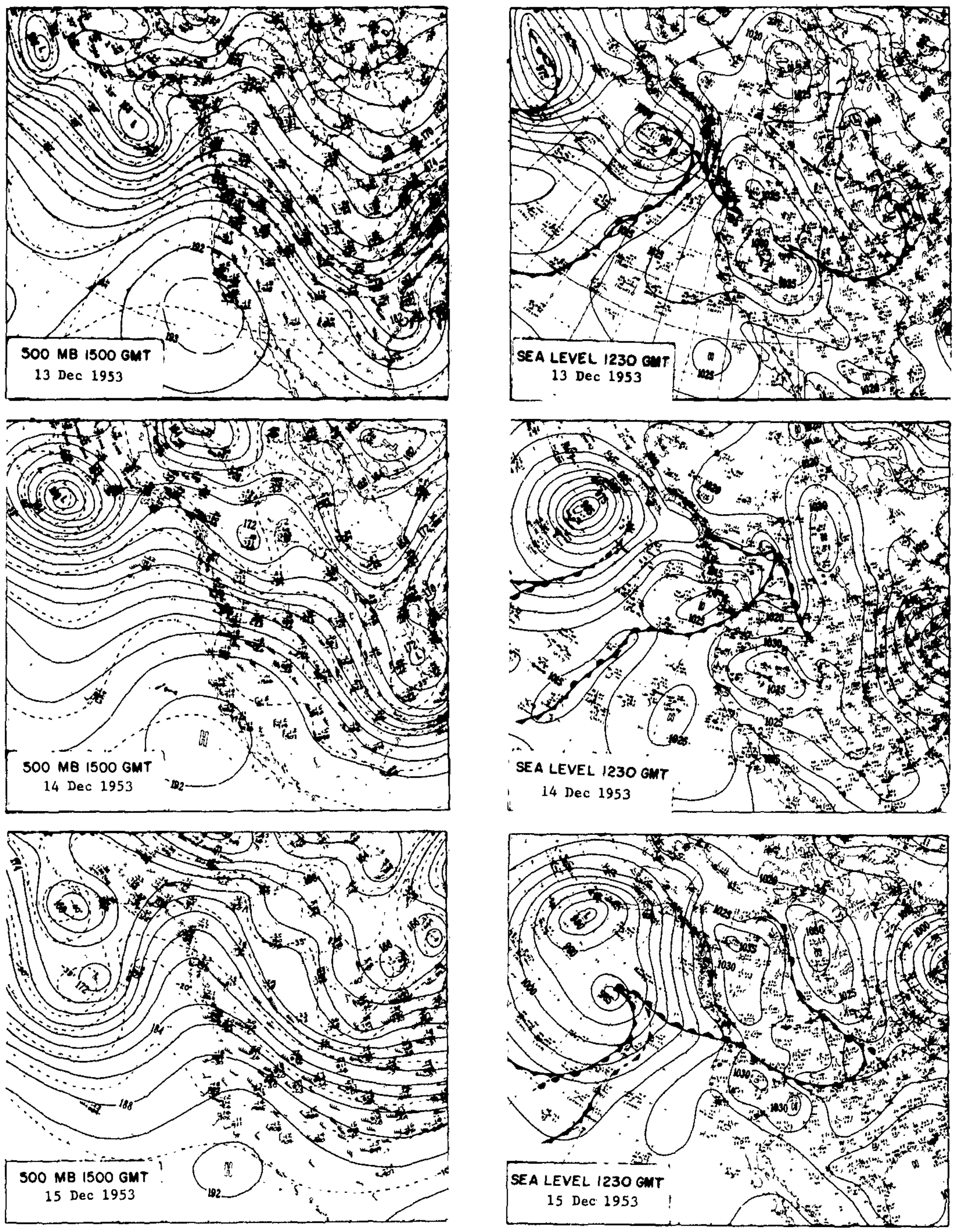


Figure 83. --Continued.

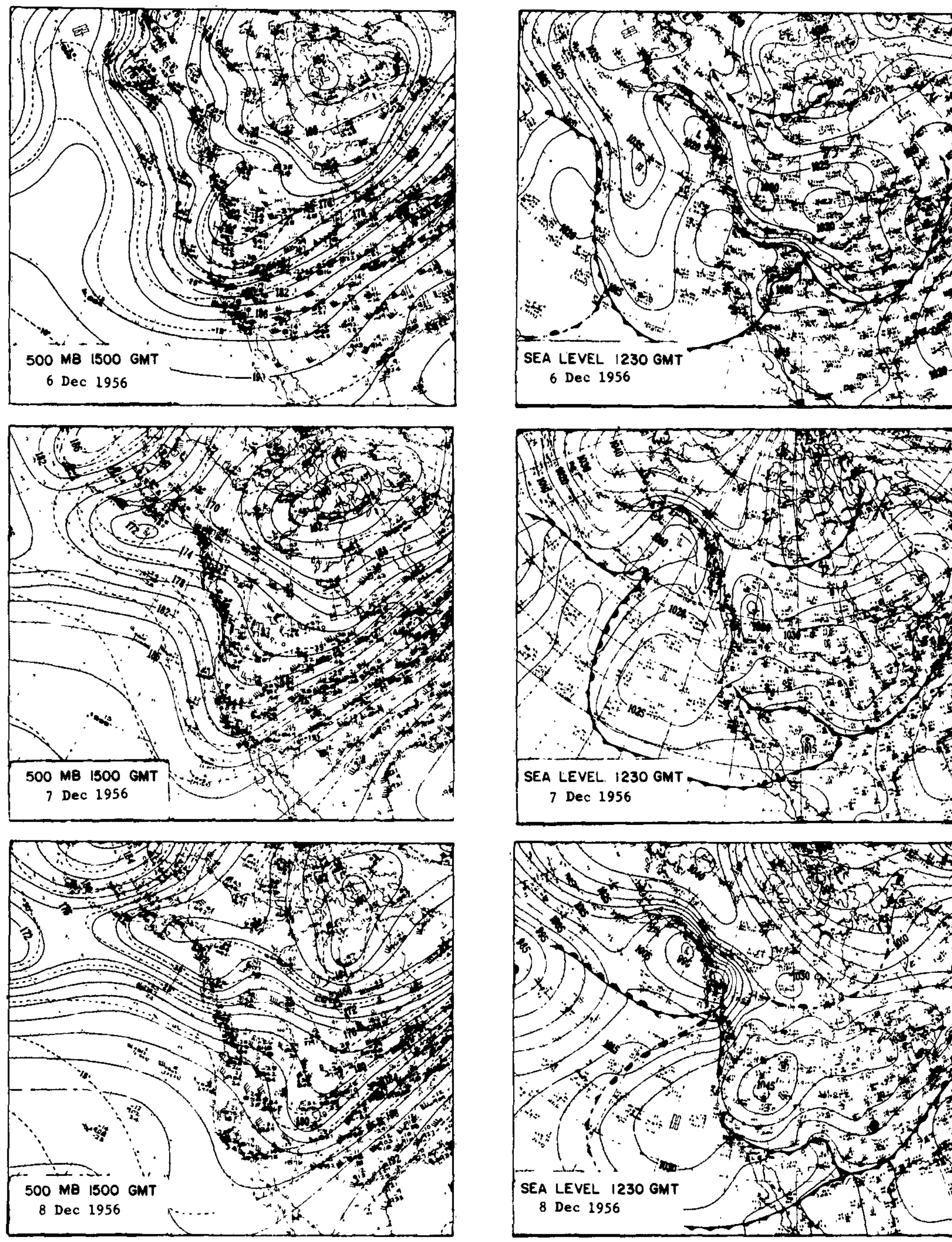


Figure 84. --Surface and 500 mb charts, December 6-11, 1956, illustrating a Santa Ana type with a Northwest Canadian High. The highest fire danger occurred December 9.

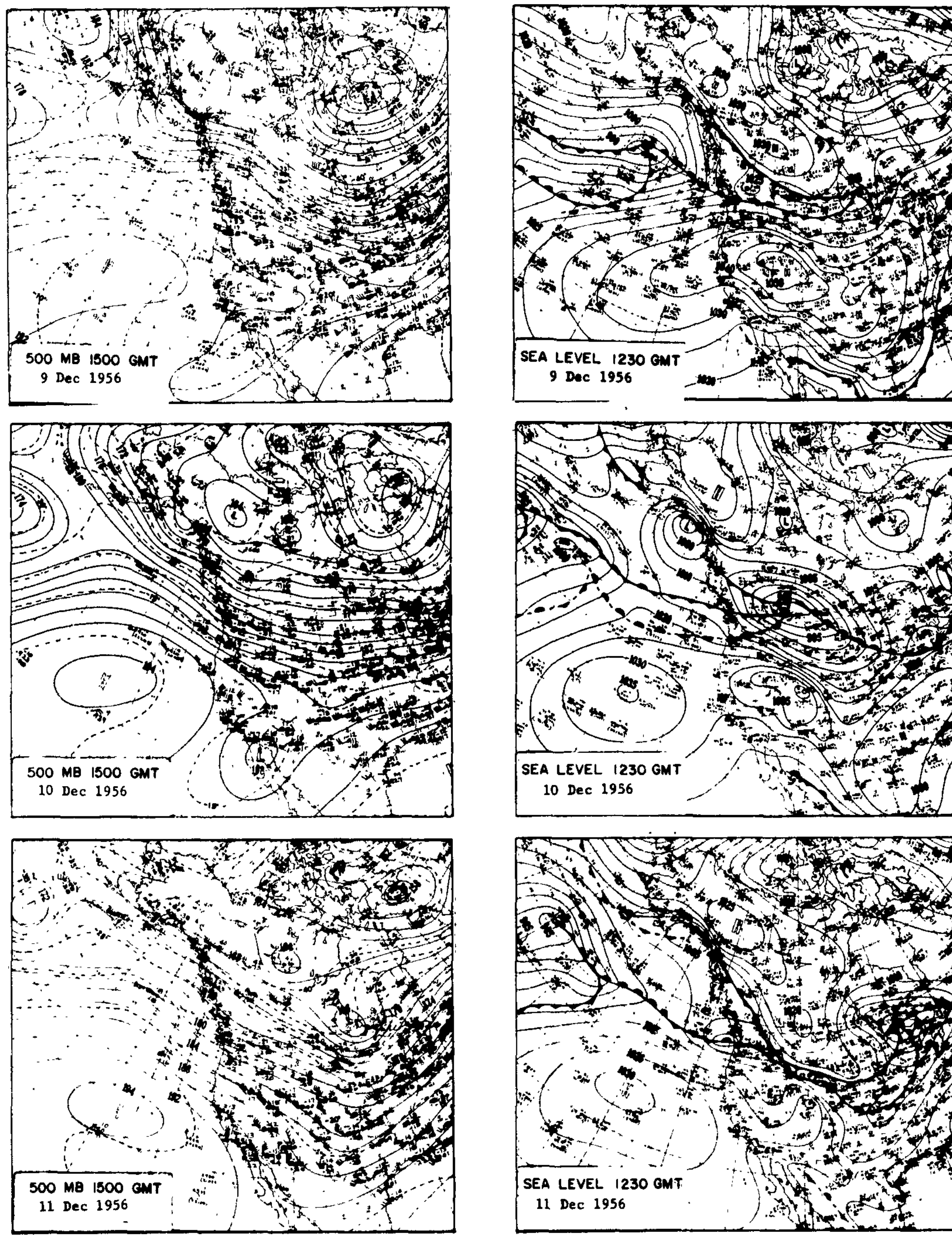


Figure 84. --Continued.

DISCUSSION

The greatest significance of this study lies in the assistance it will provide to meteorologists in predicting periods of critical fire weather. Perhaps at some future date atmospheric circulation models will be sufficiently accurate or sophisticated that long-range predictions of critical fire weather can be made by electronic computer. Until then, however, the best approach lies in the recognition by meteorologists of the development of synoptic weather patterns and types that produce critical fire-weather periods. The meteorologist can then apply his analytical techniques and forecasting aids, such as the prognostic weather maps available from the National Meteorological Center.

Although the descriptions of the fire weather types given here should be helpful in prediction, they cannot be used blindly. The forecaster needs to recognize the limitations of this study, and, in fact, the limitations of the use of synoptic types in forecasting.

This study has so far looked at the problem of the association of synoptic weather patterns and types with critical fire weather from only one side. The periods of high fire danger were selected from computed fire danger indexes, and weather maps were studied to determine the weather patterns that produced high fire danger. For one reason or another, these patterns will appear at times without producing high fire danger. Previous precipitation may be one reason; the season of the year may be another. Antecedent weather was not considered in this study except as it affected the moisture content of heavy fuels. The forecaster will need to evaluate subjectively the effect of this and other factors.

The antecedent weather and its effect on fuels in the forecast region must be considered in each case. Obviously, if the region has experienced considerable rain just before one of the types influences the fire weather, the fire danger will not be as severe as if the previous period were dry. Snow on the ground covering fuels may make it nearly impossible for fires to start and spread even though the air mass properties are favorable. Some of the weather types, however, will quickly evaporate snow, expose the fuels and dry them out, and produce a serious fire situation before the type has run its course.

Air mass properties in source regions will differ with seasons and with changes in the character of the underlying surface. A Hudson Bay High type, for example, may look much the same in summer and winter if only the pressure pattern is considered. In the wintertime, however, the air mass may be much too cold to produce a critical fire-weather situation. Even during a single season, changes in the character of the earth's surface in the source region will alter air mass properties. In early spring while Hudson Bay is ice-covered, the overlying air mass will tend to be cool but quite dry; later in spring after the ice has melted, the air mass will be somewhat warmer and more moist.

Changes in the character of the surface over which the air mass subsequently travels must also be considered. Again using the Hudson Bay High type as an example, in the spring of the year, the air mass will not pick up much moisture in moving from its source region into the United States. In summer, however, after the many small lakes over which it travels have warmed up, and vegetation and trees have begun or accelerated their growth, evaporation and transpiration will add considerable moisture to the air mass and make the fire danger less severe.

As experienced synoptic meteorologists know, weather types are not always distinctive. Pressure patterns do not change abruptly from one type to another. The change is always gradual, and usually the meteorologist is confronted with pressure patterns that are not ideal examples of the types. Frequently, there are complicating factors. Fire-weather types are no exception to this general limitation of forecasting by synoptic types. No two cases are exactly alike. The research meteorologist must allow himself considerable latitude in grouping cases into types. Similarly, the forecaster will need to use considerable subjectivity in determining whether a particular case fits into one of the synoptic types. Within each type there will be many variations. These variations could be grouped into subclassifications in order to achieve more refinement. This, however, is beyond the scope of the present study, which has been concerned only with the very broad aspects of the problem. Future grouping into subclassifications probably is best done by studies within individual regions.

Broad weather types will affect different localities differently. The forecaster who is concerned with making predictions for local areas will need to consider factors that affect local weather. Topography is one of the most important factors. As far as fire weather is concerned, it makes considerable difference whether the air flow is upslope or downslope, or whether the flow is from land to water or water to land. In predicting periods of high fire danger, the forecaster is concerned with combinations of strong winds, high temperatures, low relative humidities, and lack of precipitation. Pressure gradients, degree of subsidence, and amount of upslope or downslope flow are some of the factors that affect these weather parameters and must, therefore, be evaluated for each case.

The statistics on the frequency of the weather types given in this report are only for those cases which produced high fire danger. How often do these types and patterns actually occur during each month or season of the year? What values and variations of the weather parameters and fire danger indexes can be expected with each type? These questions are now being studied by looking at the other side of the problem. The surface and upper-air charts for the years 1951-60 are being analyzed to determine the number of times that each type and pattern has occurred during that period. The stations that are affected by each case are being tabulated. The range, central tendency, and a measure of the variation of each important weather parameter and fire danger index will be calculated by electronic computer. This information will be included in a separate report scheduled for completion June 30, 1965. When it is available, this information should further aid the forecaster in making predictions of critical fire weather.

This study was concerned only with critical fire weather types. Another aspect of fire weather that needs a similar study is just the opposite--that is, what are the synoptic weather types that produce "safe" fire weather conditions? For Civil Defense planning purposes, it should be useful to know the weather situations under which mass fire would not spread, and would go out even in the absence of fire control.

The snow-cover probability charts in Appendix B cover only the period from the first week in December through the last week in March. Obviously this coverage is incomplete because some areas have 100 percent probability of snow cover the first and last weeks of the periods. The expense of extracting the necessary data from original weather records and computing similar probabilities for weeks before and after this period would be considerable. Nevertheless, the value of the completed set of charts for long-range planning purposes should justify the undertaking of this task.

CONCLUSIONS

1. Periods of critical fire weather are associated with synoptic patterns and types as follows:

    a. East of the Rocky Mountains most of the high fire danger occurs around the periphery of high pressure cells, particularly in the pre-frontal and post-frontal areas.

    b. The Atlantic and Gulf coasts occasionally have, in addition to the above, high fire danger associated with tropical storms in the windy area beyond the rain and cloud shield.

    c. Along the eastern slopes of the Rockies the important weather types are those producing a foehn effect, locally known as a Chinook.

    d. In the mountain and intermountain regions, short-wave troughs moving along the jet stream cause peaks in fire danger, as do surface dry-front passages.

    e. Along the West Coast patterns producing heat waves and patterns resulting in foehn-type wind or offshore flow are important.

2. With the proper consideration given to season, antecedent weather, surface and fuel conditions, and effects of topography, the descriptions of the patterns and types provide fire-weather meteorologists with a means of anticipating periods of critical fire weather in local areas.

3. In this study a first broad-scale, nation-wide look at the problem of critical fire weather periods was completed. Refinement can be obtained through additional study.

RECOMMENDATIONS

1. Continue and conclude the task of determining the frequency of occurrence of the critical fire-weather types and statistics of weather parameters and fire danger indexes associated with them.

2. Refine the classification of types, possibly by subclassifying according to the effect on fire weather in severity, extent, or portion of region covered. Determine also:

    a. The degree to which antecedent weather may modify the effectiveness of each type.

    b. The variations in effectiveness caused by seasons.

    This refinement could best be carried out within regions where more detailed information on fire danger conditions can be considered and where the problem is close at hand.

3. Investigate the synoptic weather types that produce "safe" fire weather conditions.

4. Complete the determination of snow-cover probability for the entire winter season by calculating the probabilities for October, November, April, and May.

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APPENDIX A

FREQUENCY DISTRIBUTION OF FIRE LOAD INDEX

Since it was necessary to compute the fire danger indexes for a nation-wide network of stations to determine the periods of high fire danger, it was felt that tabulations of frequency distribution of these indexes would provide further useful information on the occurrence of high fire danger. Accordingly, by electronic data processing, the following were computed for each of the five fire danger indexes by months:

1. Frequency by class intervals of five units
2. Percent frequency by class intervals of five units
3. Accumulated frequency
4. Accumulated percent frequency

Also, the frequency and percent frequency were computed for the following values of fine fuel moisture:

1.5	4.5-5.0	9.5-10.0	15.0
2.0	5.5-6.0	11.0	16.0
2.5	6.5-7.0	12.0	17.0
3.0	7.5-8.0	13.0	18.0
3.5-4.0	8.5-9.0	14.0	

Tabulation of these data, in the form illustrated by figures 85 and 86, have been compiled for all five indexes and for fine fuel moisture, but only the fire load index is presented in this Appendix in graph and map form.

The first set of graphs consists of bar charts showing the distribution of fire load index values in percent frequency by months for each station.

The second set of graphs contains curves of accumulated percent frequency of fire load index values for each station by months.

Third is a set of maps of the 25th, 50th, 75th, and 99th percentiles of fire load index by months. These maps show the area distribution of fire load index occurrence for each month. Isolines are sketched for intervals of 10 units.

The arrangement of the two sets of graphs follows the order of the discussion of regional weather patterns, starting with the 10 stations in the Northeast Region and ending with the two stations in the Southern California Region.

STATION 23160 JAN , 1951-60 SPREAD INDEX

INDEX	NO. OF OCCUR.	CLASS OCCUR.	FREQ PERCENT	CUM FREQ PERCENT	INDEX	NO. OF OCCUR.	CLASS OCCUR.	FREQ PERCENT	CUM FREQ PERCENT
0	11			3.55	50	0			94.52
1	0			3.55	51	2			95.16
2	0			3.55	52	1			95.48
3	3			4.52	53	0			95.48
4	3	17	5.48	5.48	54	0	3	0.97	95.48
5	5			7.10	55	0			95.48
6	11			10.65	56	1			95.81
7	12			14.52	57	3			96.77
8	15			19.35	58	0			96.77
9	13	56	18.06	23.55	59	0	4	1.29	96.77
10	14			28.06	60	1			97.10
11	23			35.48	61	0			97.10
12	15			40.32	62	1			97.42
13	37			52.26	63	0			97.42
14	19	108	34.84	58.39	64	2	4	1.29	98.06
15	3			59.35	65	0			98.06
16	14			63.87	66	1			98.39
17	11			67.42	67	0			98.39
18	1			67.74	68	0			98.39
19	12	41	13.23	71.61	69	0	1	0.32	98.39
20	16			76.77	70	0			98.39
21	4			78.06	71	0			98.39
22	5			79.68	72	3			99.35
23	6			81.61	73	0			99.35
24	0	31	10.00	81.61	74	0	3	0.97	99.35
25	2			82.26	75	0			99.35
26	4			83.55	76	0			99.35
27	0			83.55	77	0			99.35
28	4			84.84	78	0			99.35
29	3	13	4.19	85.81	79	0	0	0.	99.35
30	3			86.77	80	0			99.35
31	4			88.06	81	1			99.68
32	0			88.06	82	0			99.68
33	2			88.71	83	0			99.68
34	2	11	3.55	89.35	84	0	1	0.32	99.68
35	1			89.68	85	0			99.68
36	1			90.00	86	0			99.68
37	3			90.97	87	0			99.68
38	1			91.29	88	0			99.68
39	1	7	2.26	91.61	89	1	1	0.32	100.00
40	0			91.61	90	0			100.00
41	2			92.26	91	0			100.00
42	0			92.26	92	0			100.00
43	1			92.58	93	0			100.00
44	2	5	1.61	93.23	94	0	0	0.	100.00
45	2			93.87	95	0			100.00
46	0			93.87	96	0			100.00
47	1			94.19	97	0			100.00
48	0			94.19	98	0			100.00
49	1	4	1.29	94.52	99	0	0	0.	100.00
						TOTAL 310			

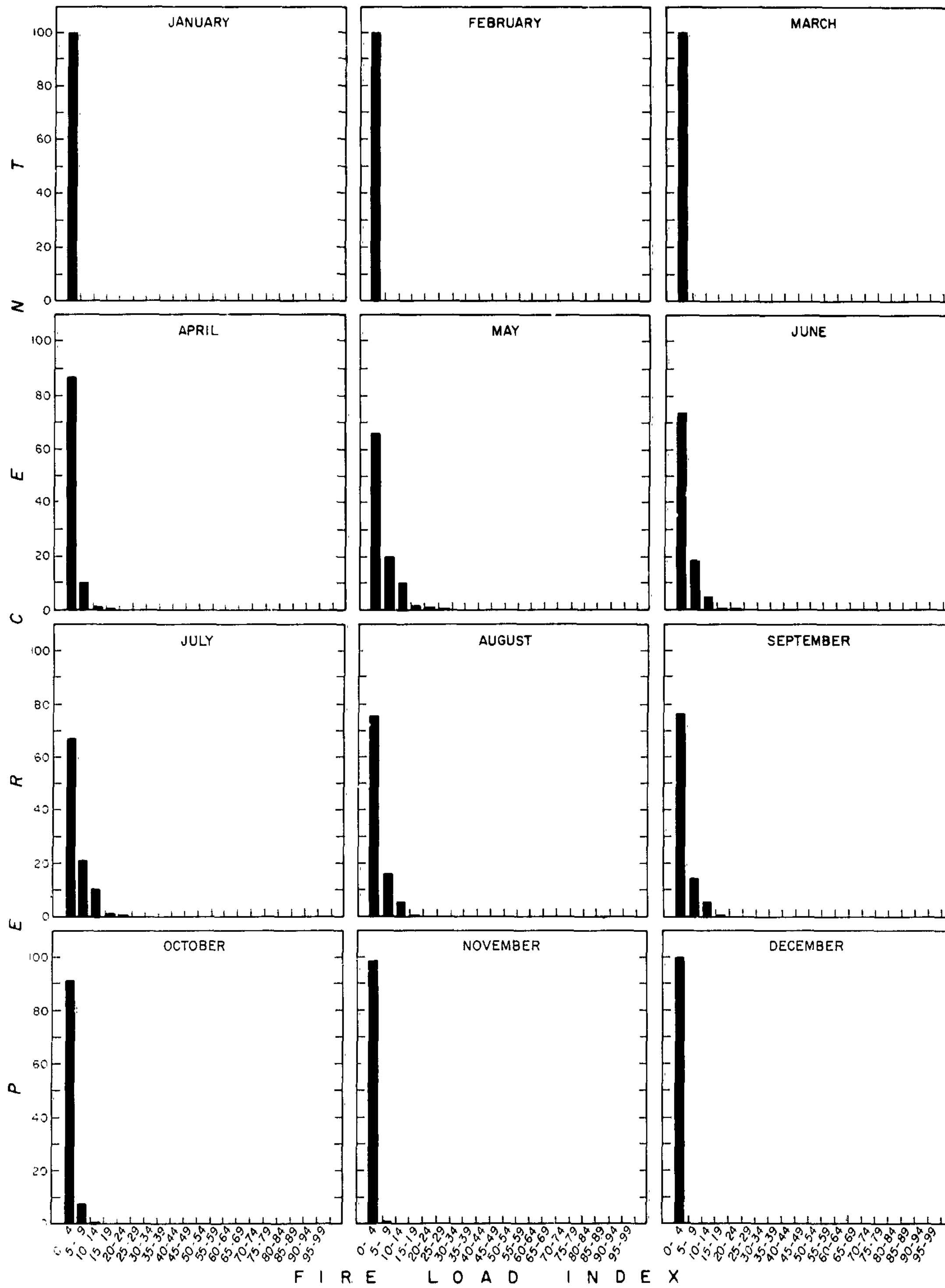
Figure 85. --Example of tabulation of frequencies of fire danger indexes.

STATION 23184 MAR , 1951-60 FINE FUEL MOISTURE

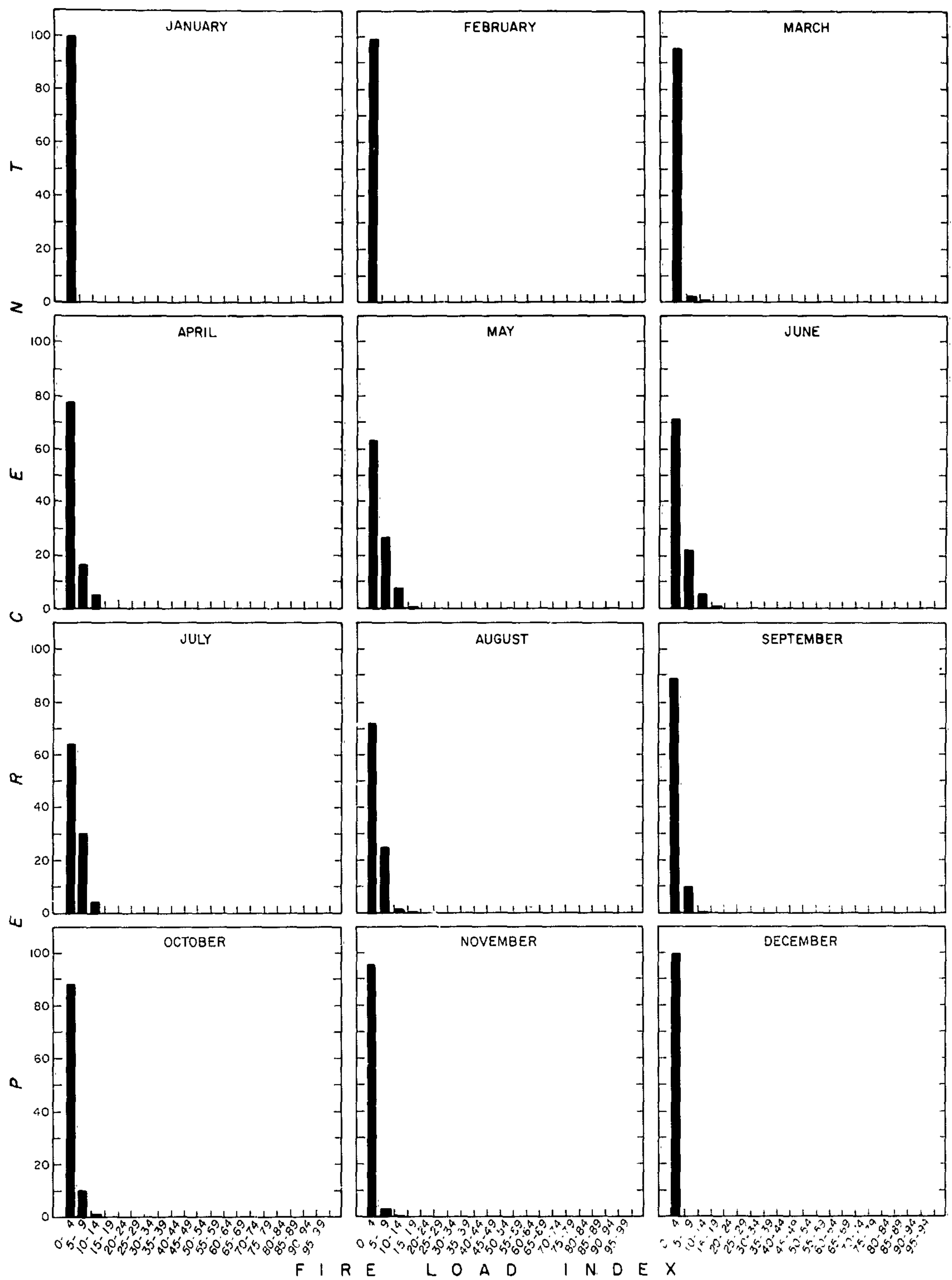
INDEX	NO. OF OCCUR.	CLASS OCCUR.	FREQ PERCENT	CUM FREQ PERCENT
1.5	14			4.52
2.0	3			5.48
2.5	25	42	13.55	13.55
3.0	32			23.87
4.0	96			54.84
5.0	38	166	53.55	67.10
6.0	35			78.39
7.0	7			80.65
8.0	13	55	17.74	84.84
9.0	8			87.42
10.0	5			89.03
11.0	5	18	5.81	90.65
12.0	5			92.26
13.0	6			94.19
14.0	3	14	4.52	95.16
15.0	2			95.81
16.0	4			97.10
17.0	3	9	2.90	98.06
18.0	6	6	1.94	100.00
	TOTAL 310			

Figure 86. --Example of tabulation of frequencies of fine fuel moisture values.

STATION 14607 CARIBOU, MAINE



STATION 14742 BURLINGTON, VERMONT



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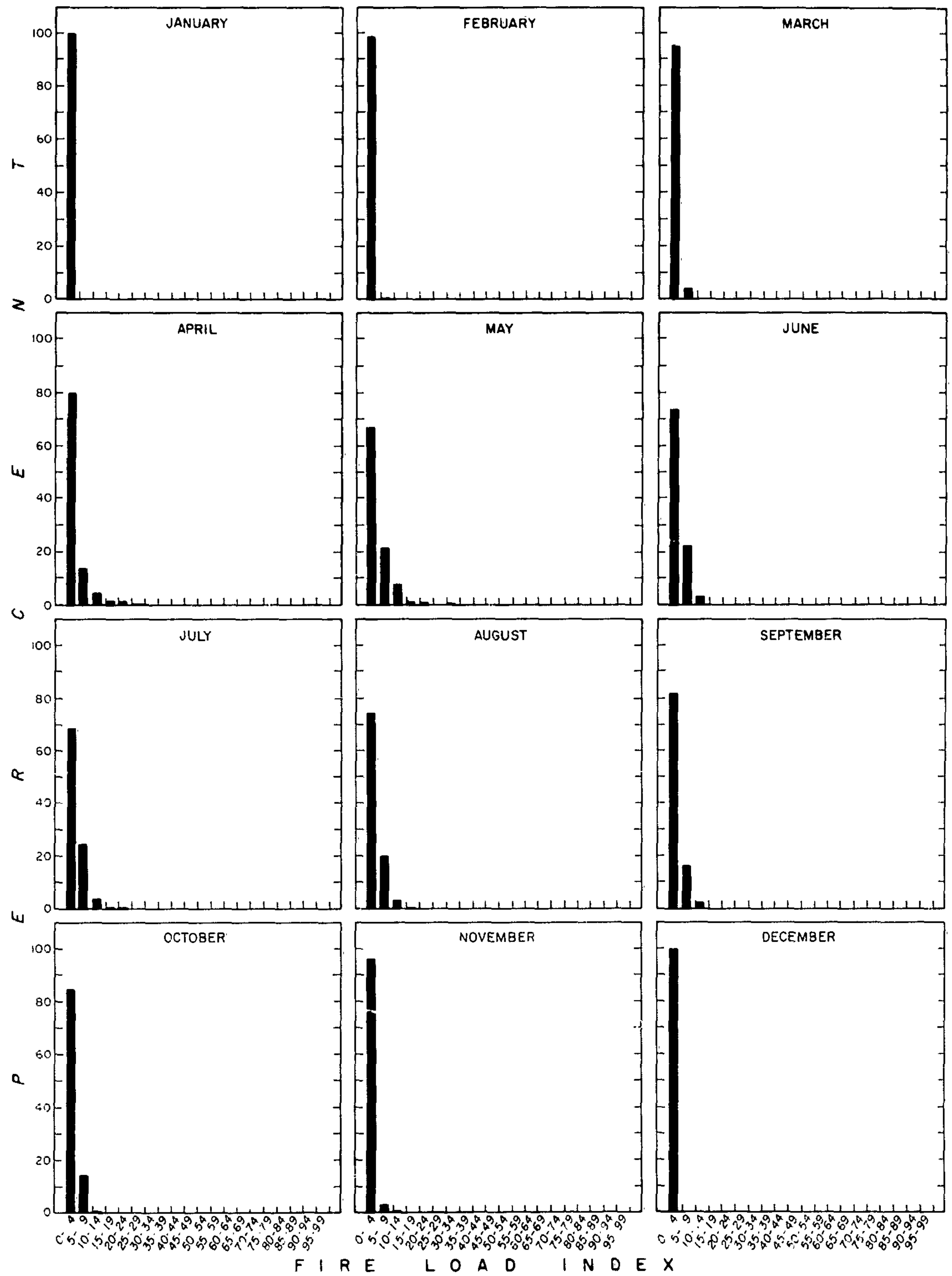
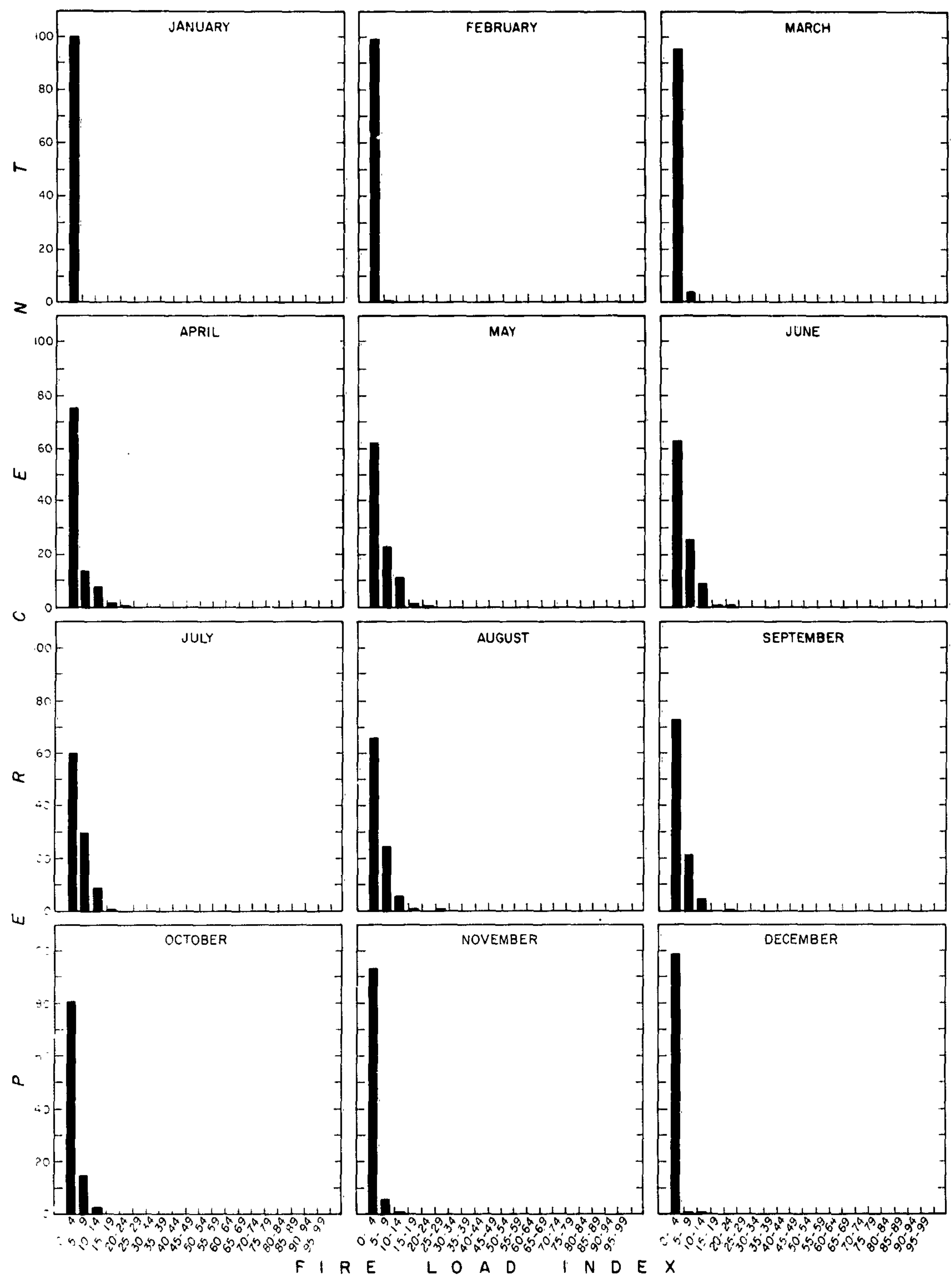
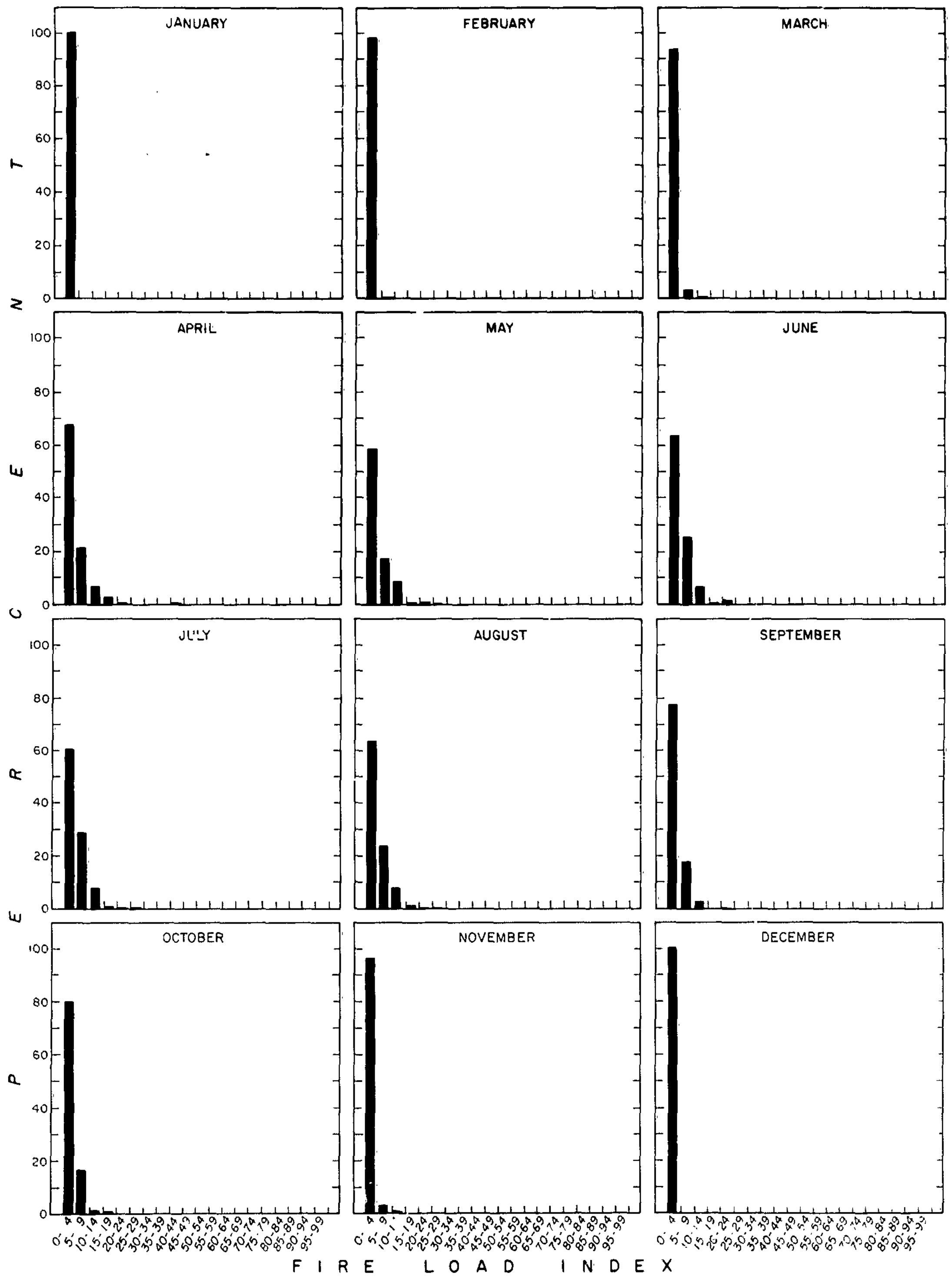


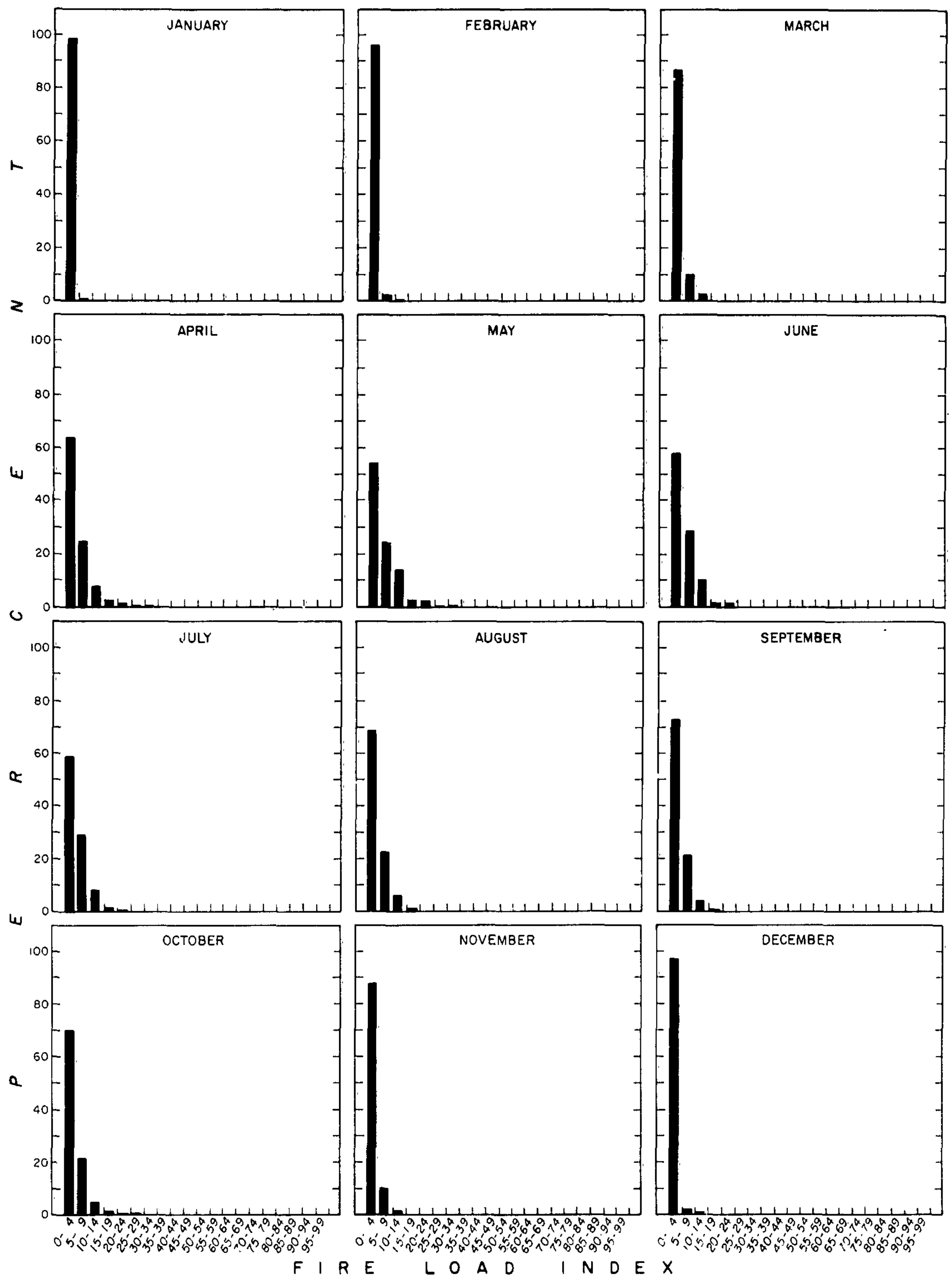
STATION 14771 SYRACUSE, NEW YORK



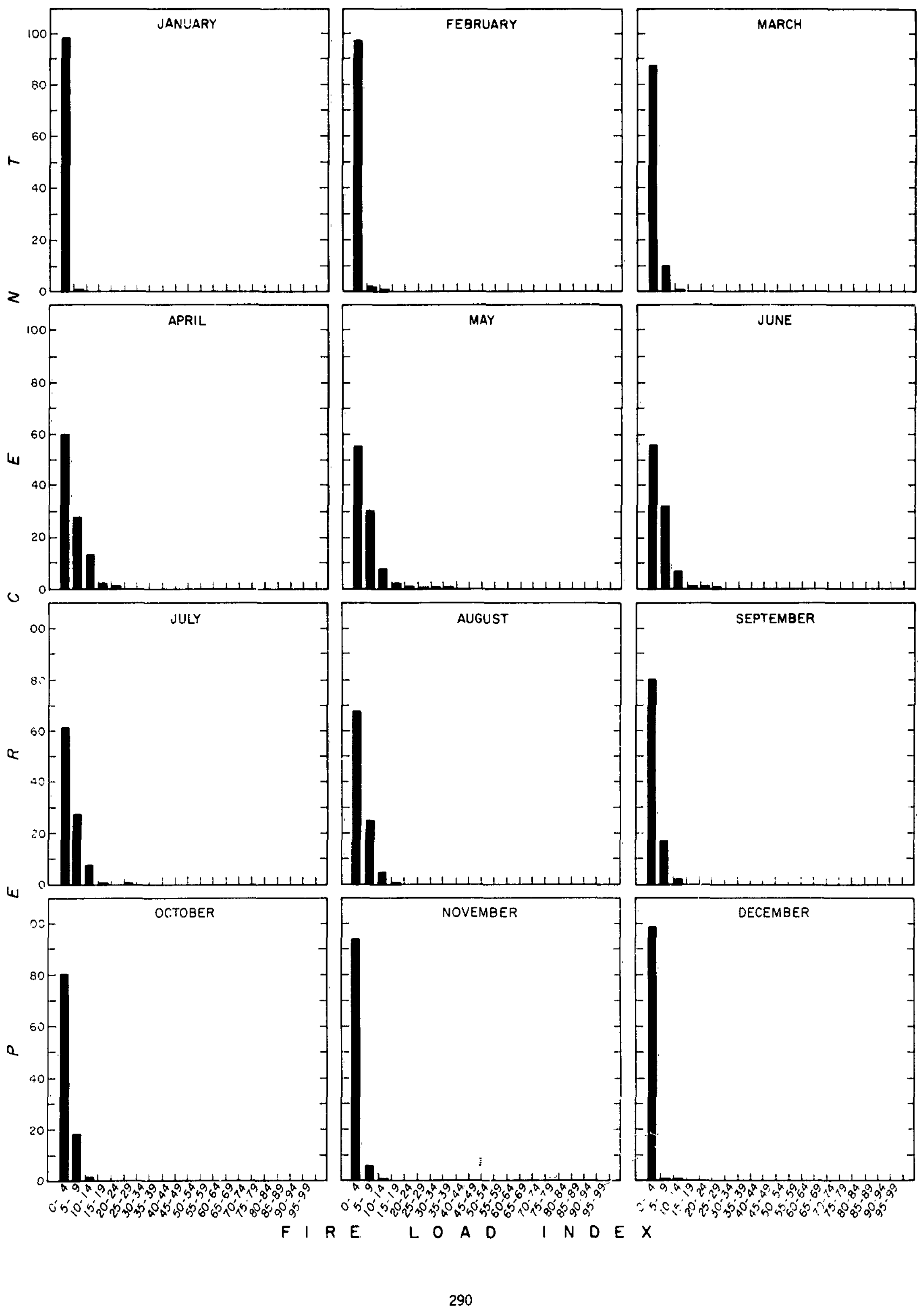
STATION 14735 ALBANY, NEW YORK



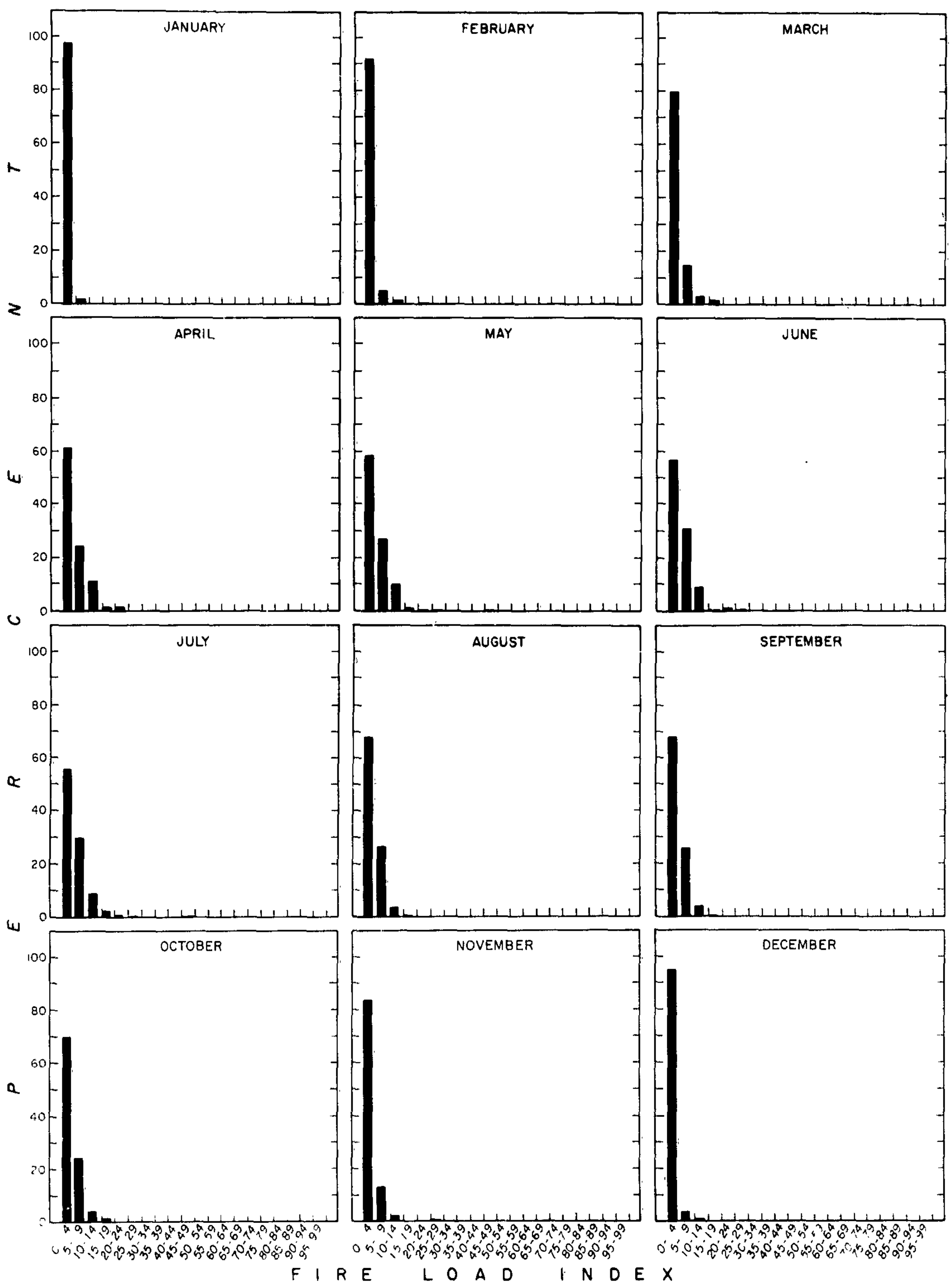
STATION 14740 HARTFORD, CONNECTICUT



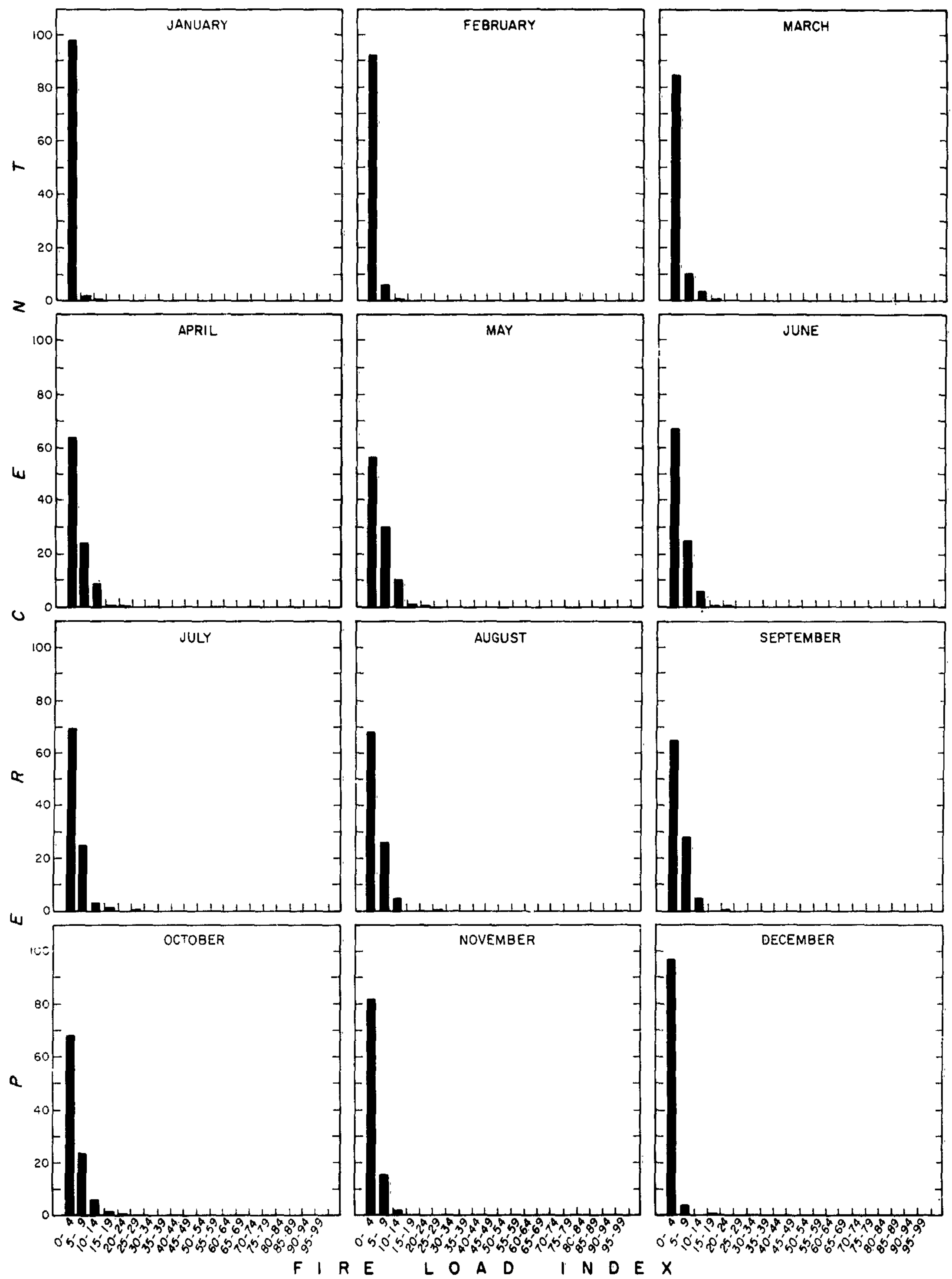
STATION 14778 WILLIAMSPORT, PENNSYLVANIA



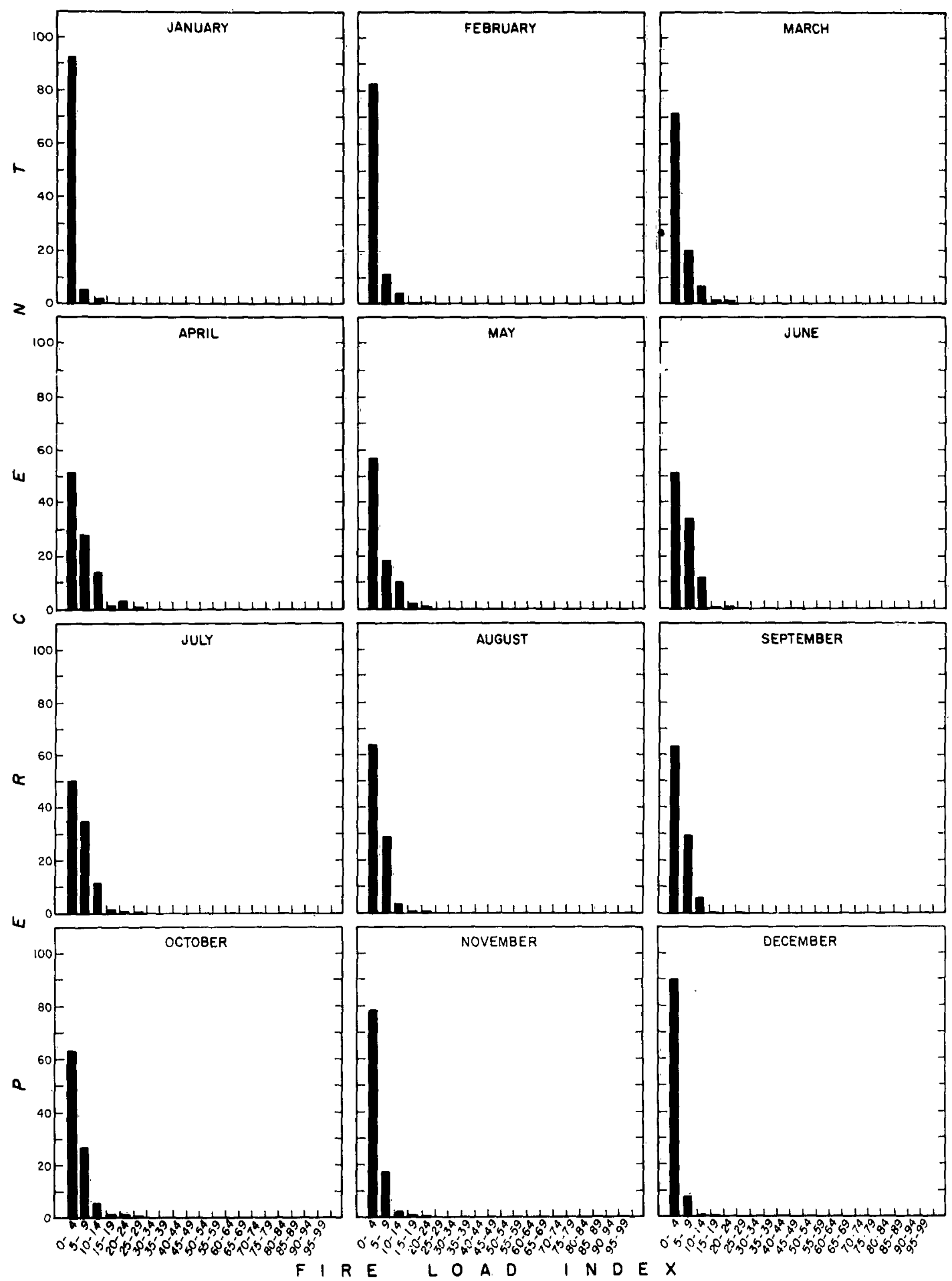
STATION 13739 PHILADELPHIA, PENNSYLVANIA



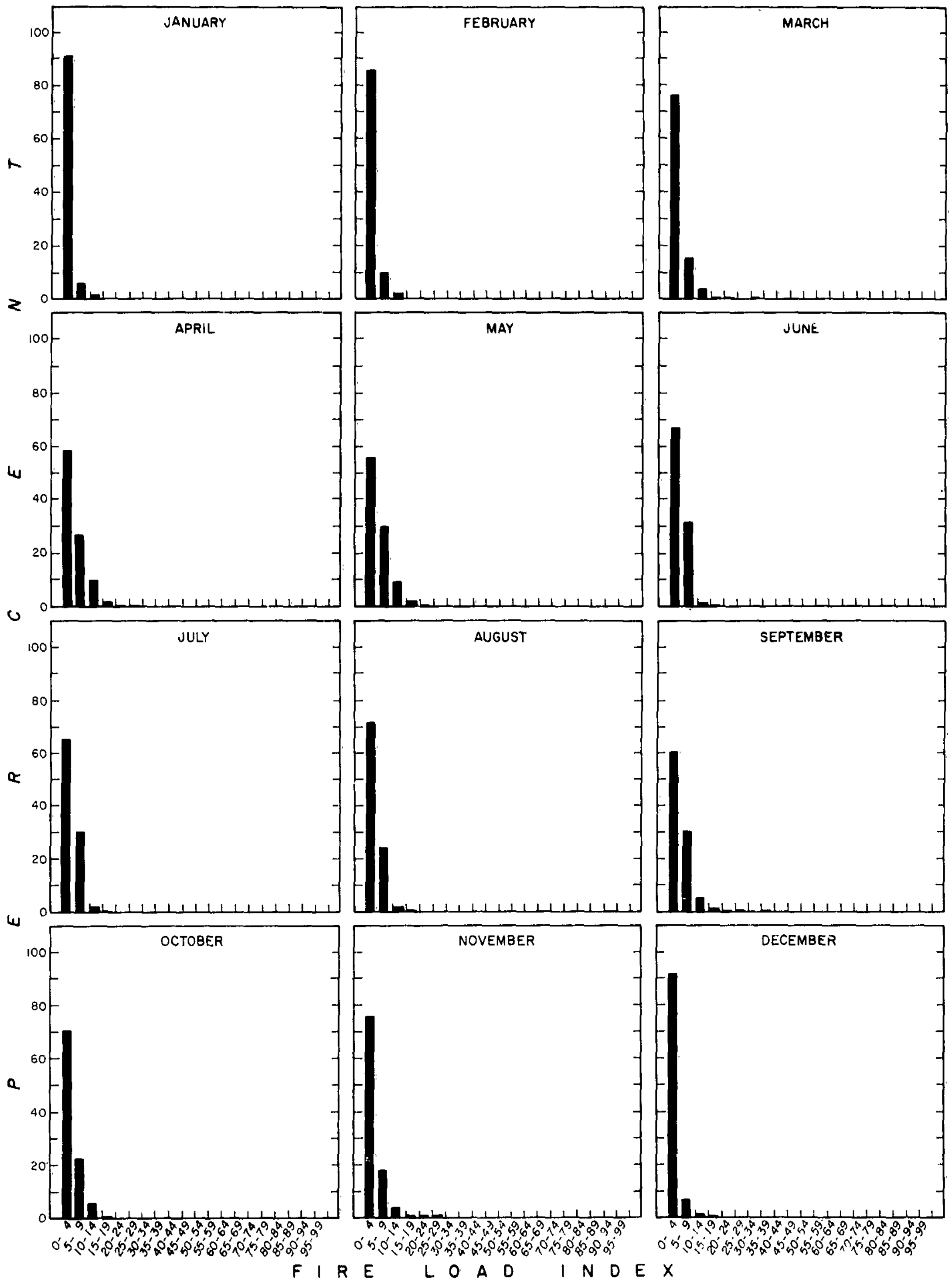
STATION 94823 PITTSBURGH, PENNSYLVANIA



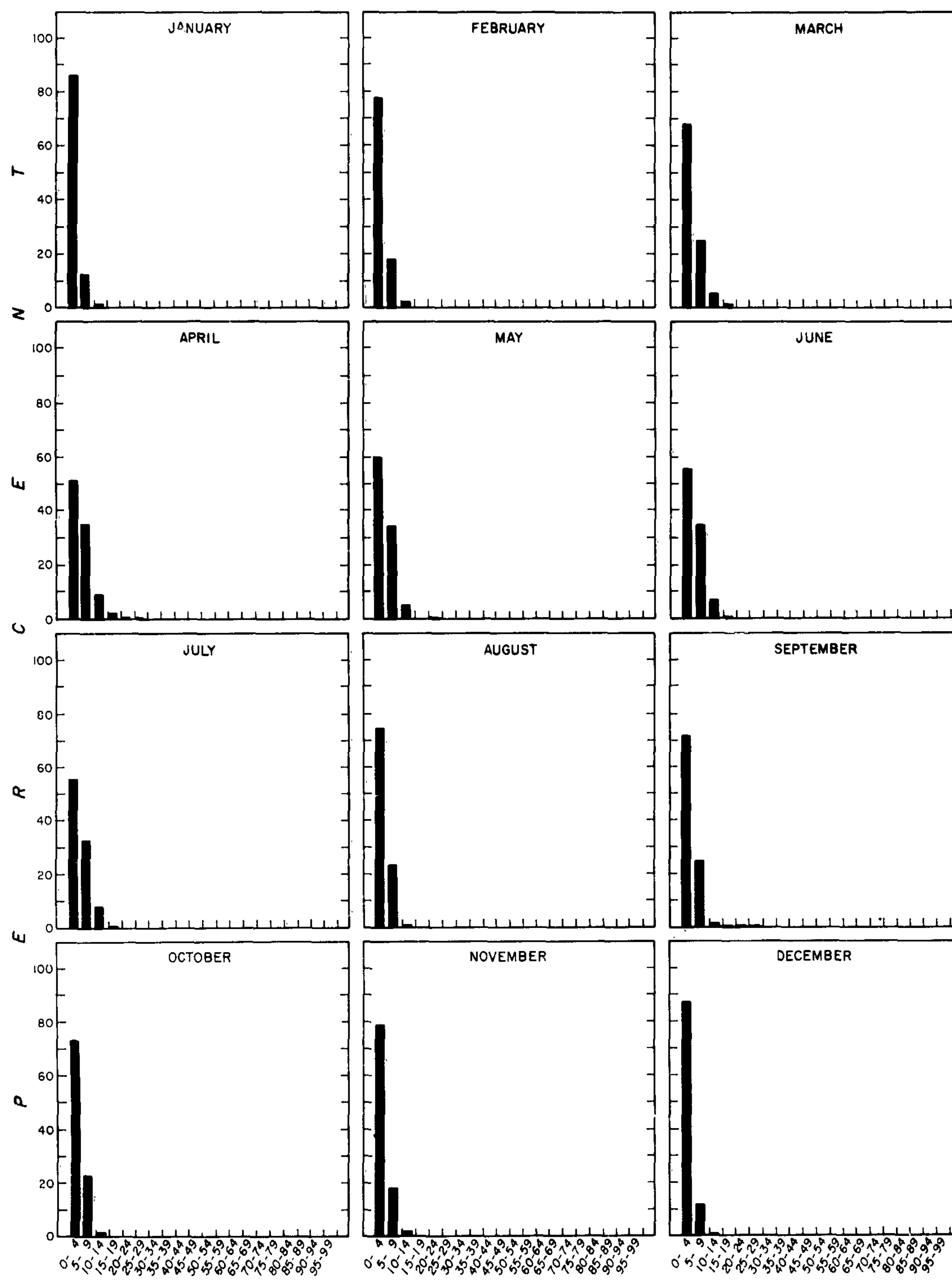
STATION 13743 WASHINGTON, D.C.



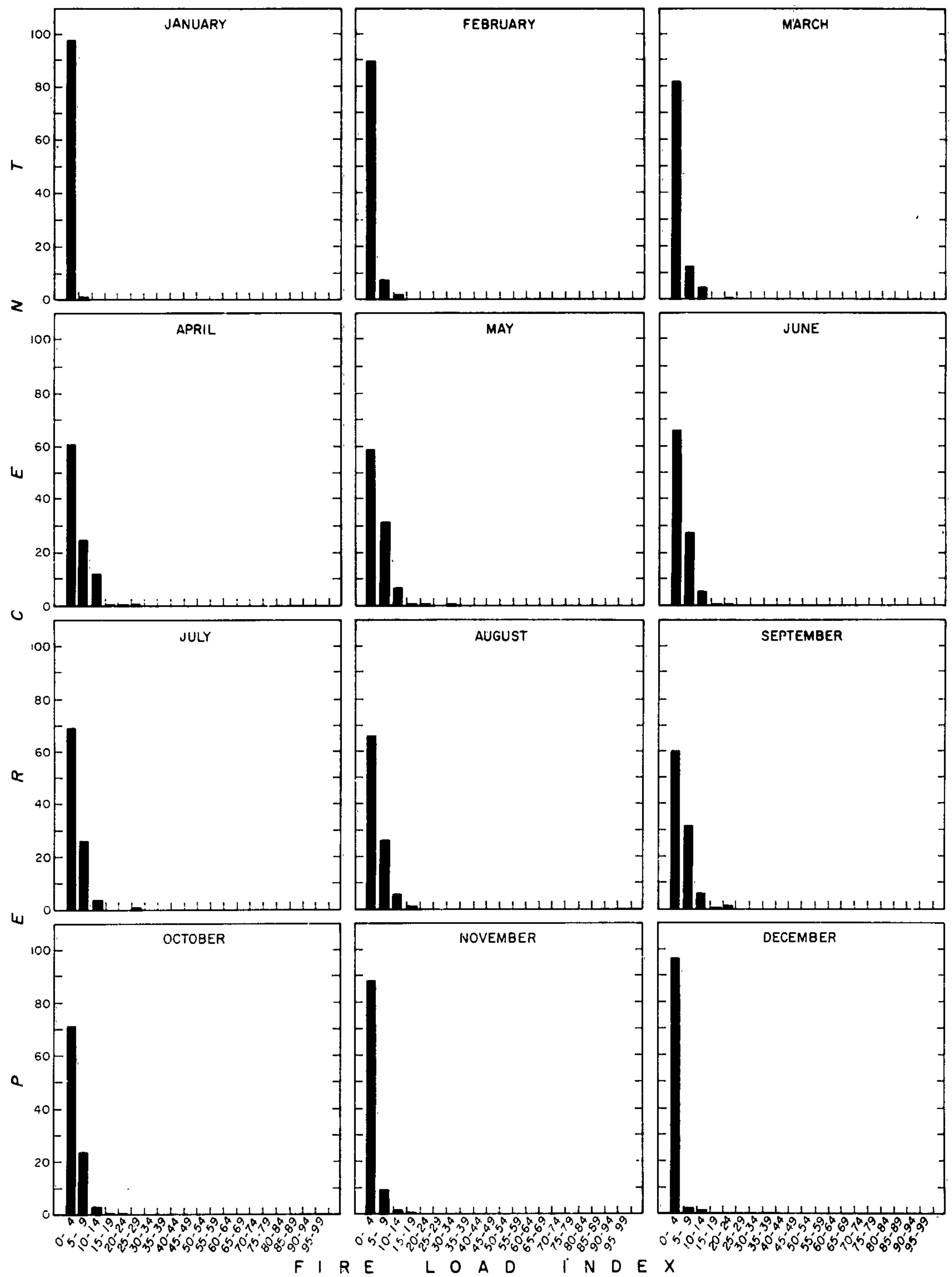
STATION 13866 CHARLESTON, WEST VIRGINIA



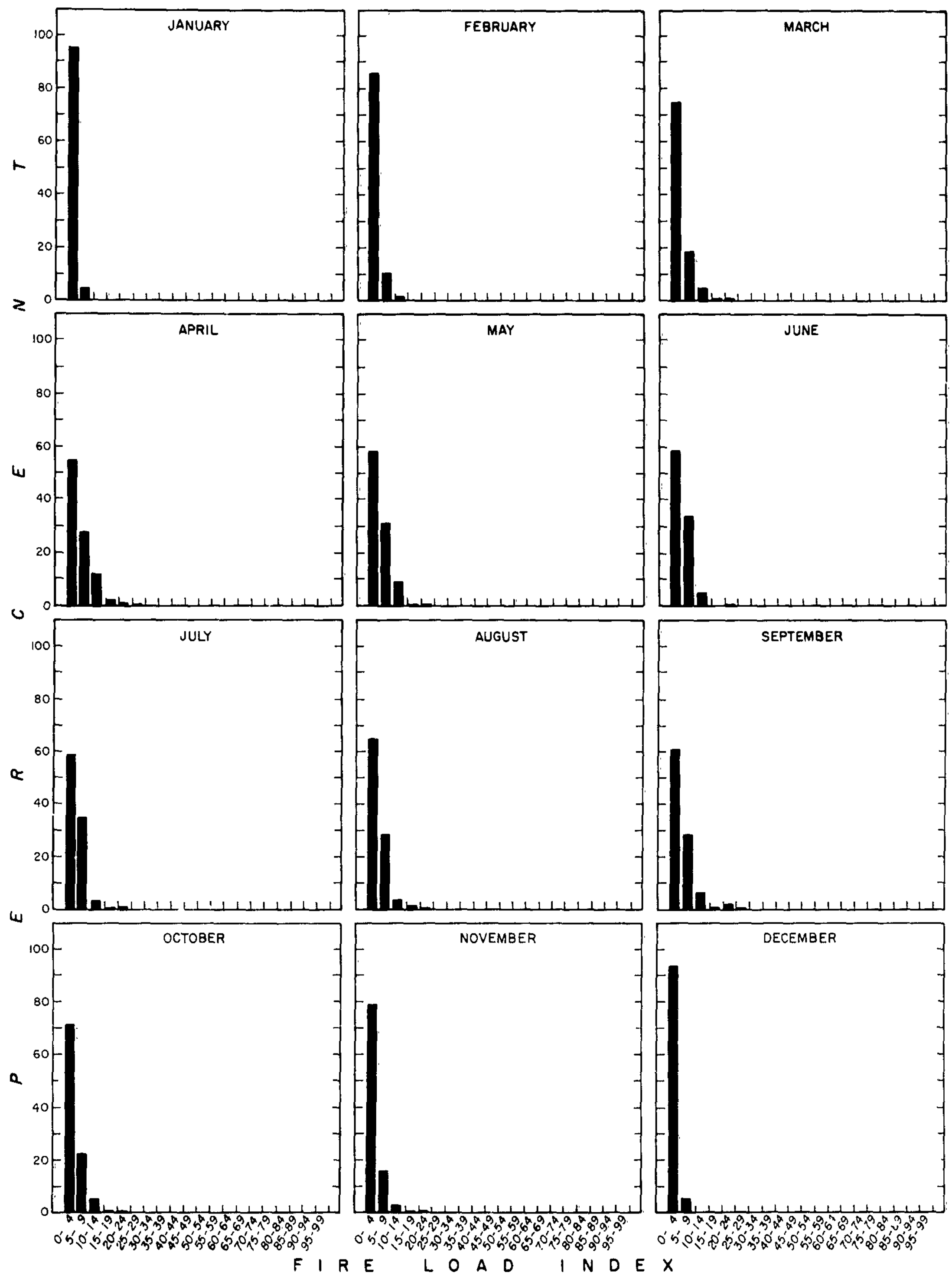
STATION 13740 RICHMOND, VIRGINIA



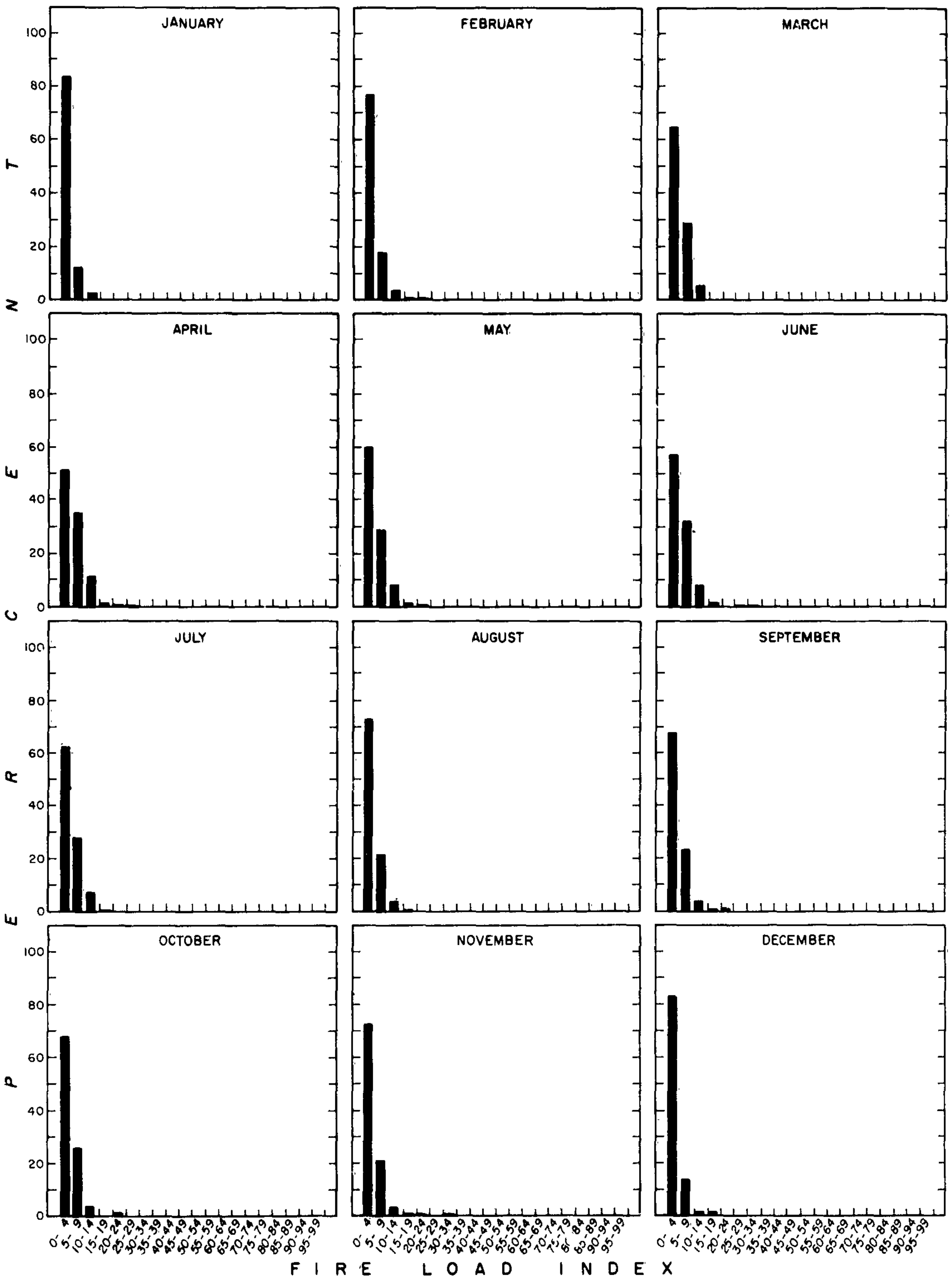
STATION 13891 KNOXVILLE, TENNESSEE



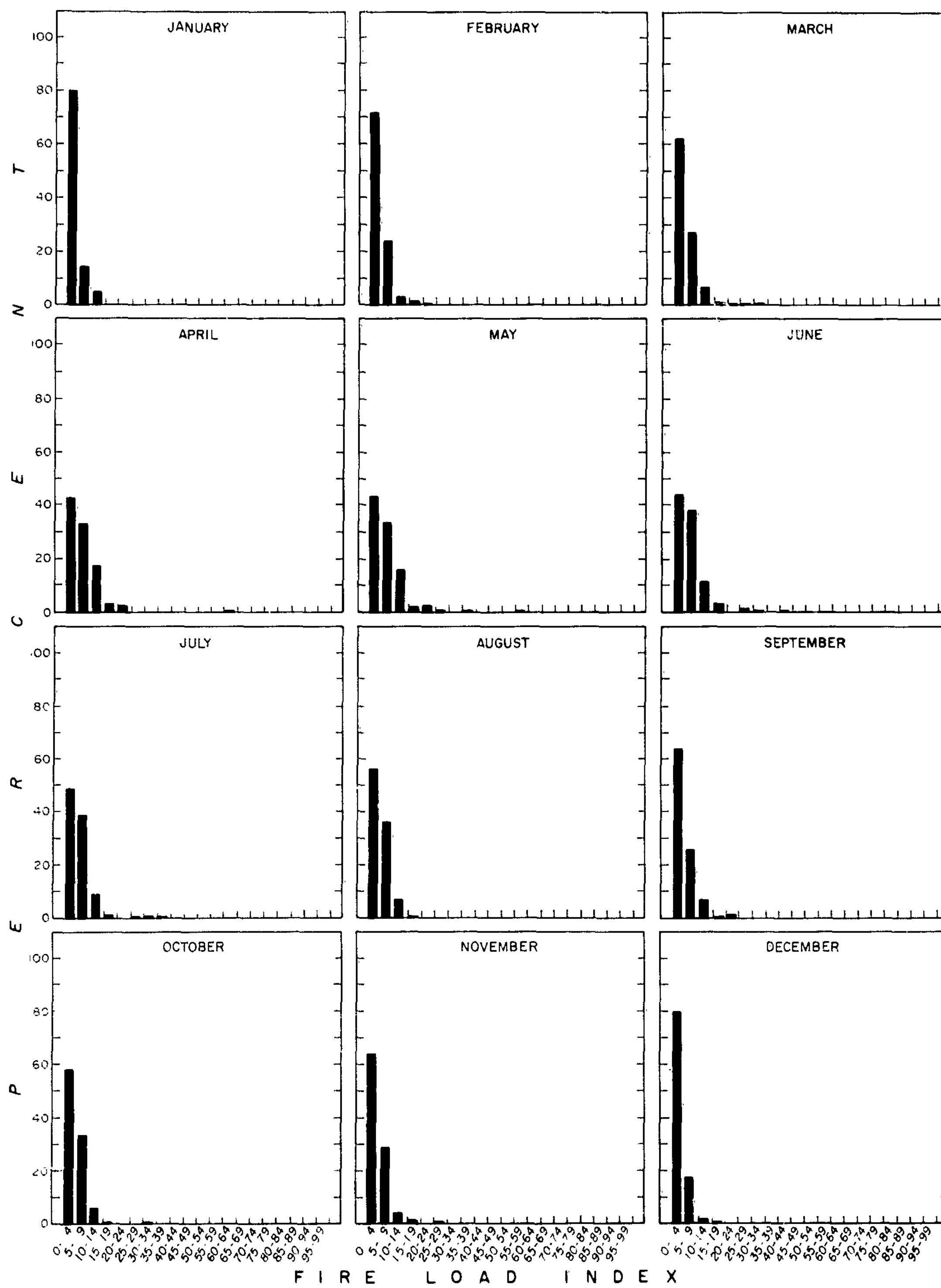
STATION 13882 CHATTANOOGA, TENNESSEE



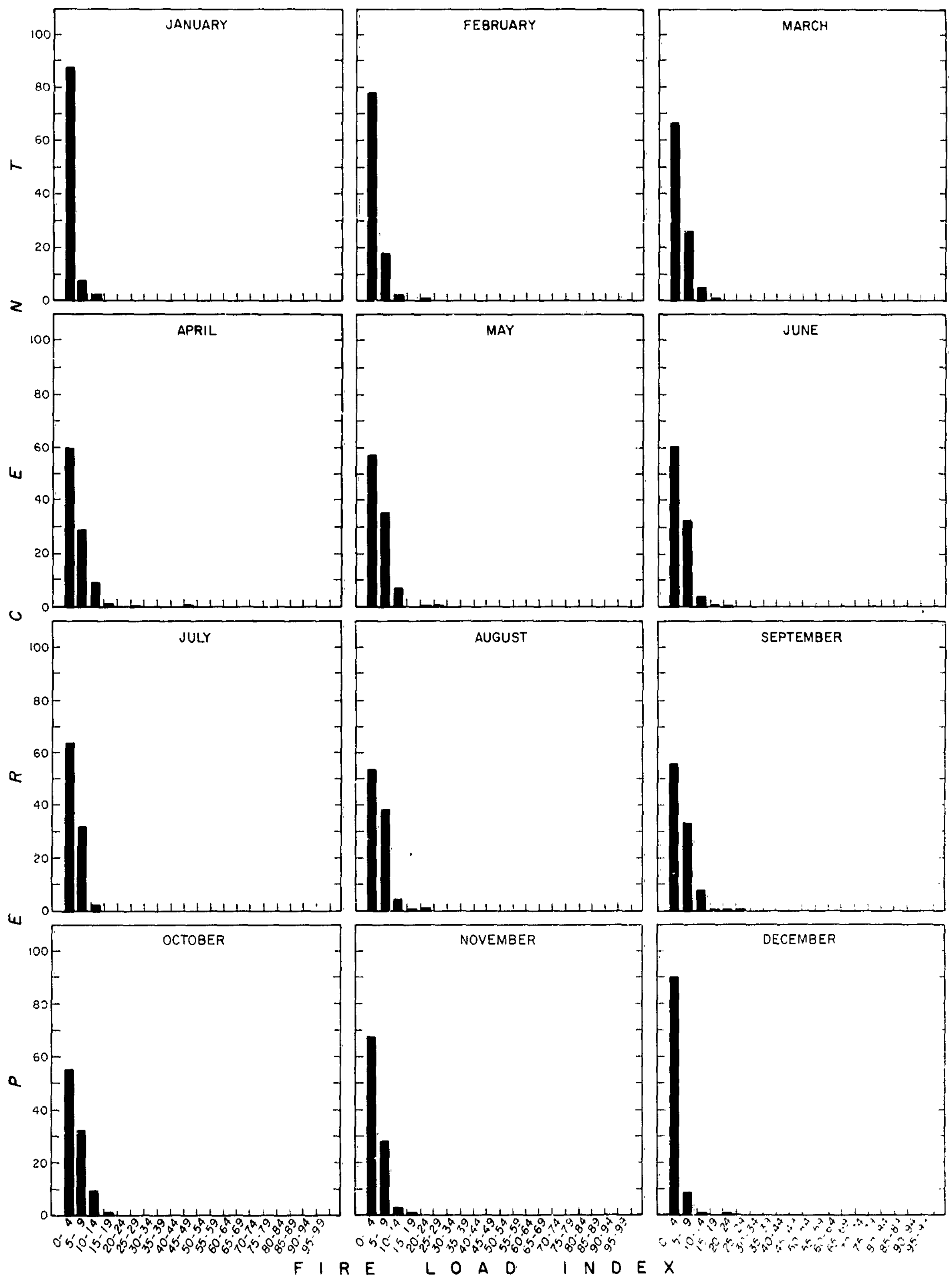
STATION 13722 RALEIGH, NORTH CAROLINA



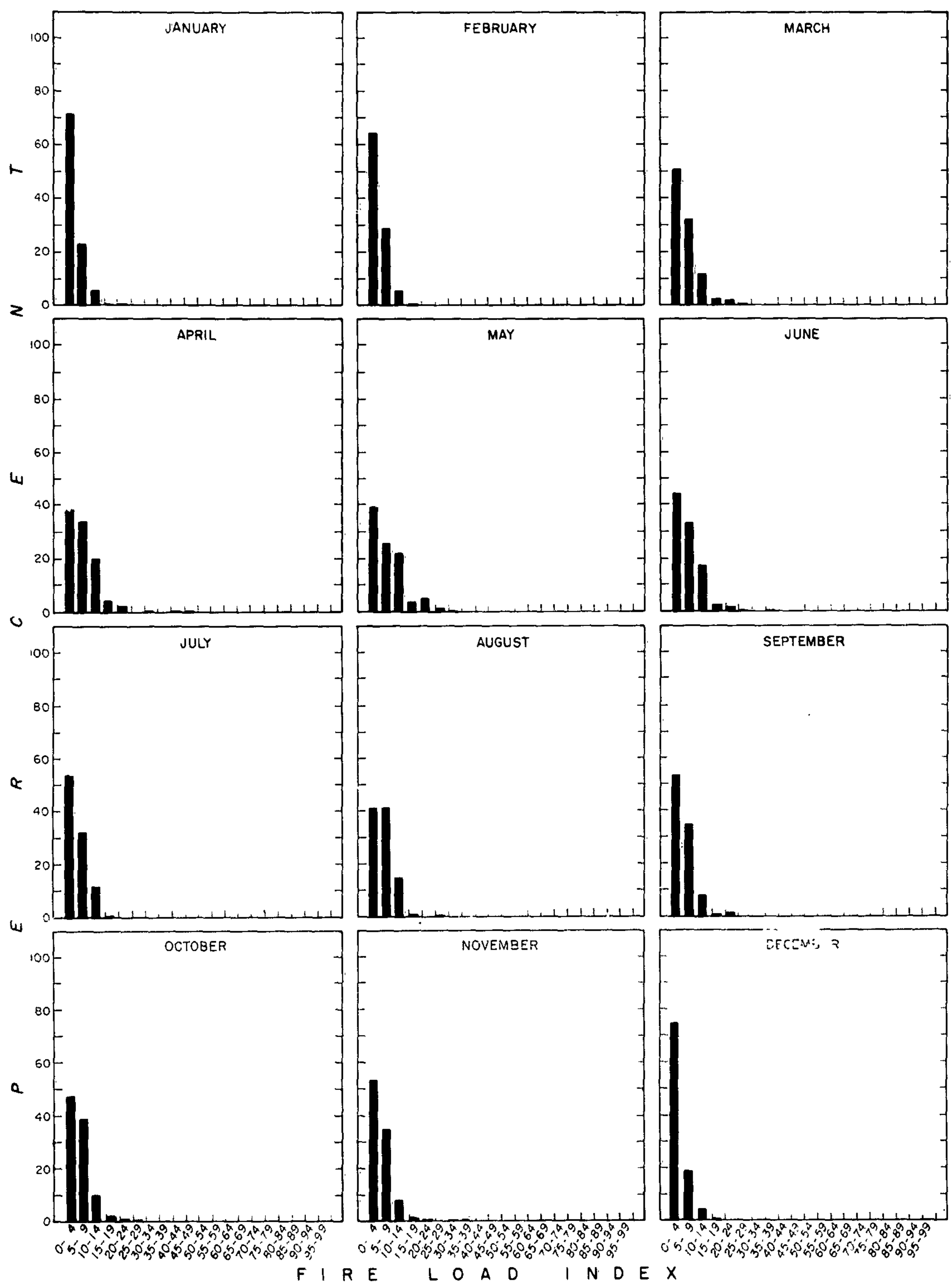
STATION 13883 COLUMBIA, SOUTH CAROLINA



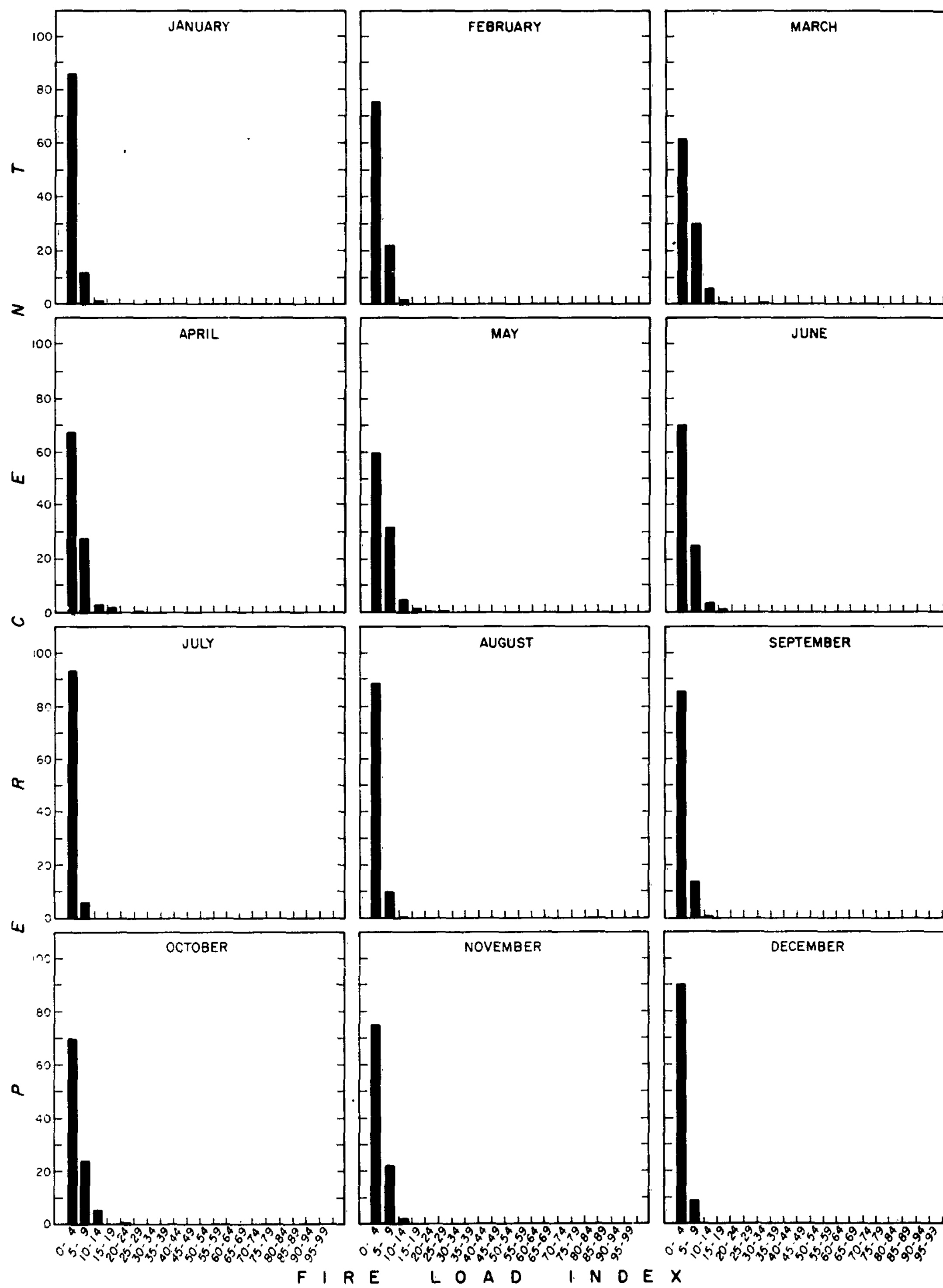
STATION 13895 MONTGOMERY, ALABAMA



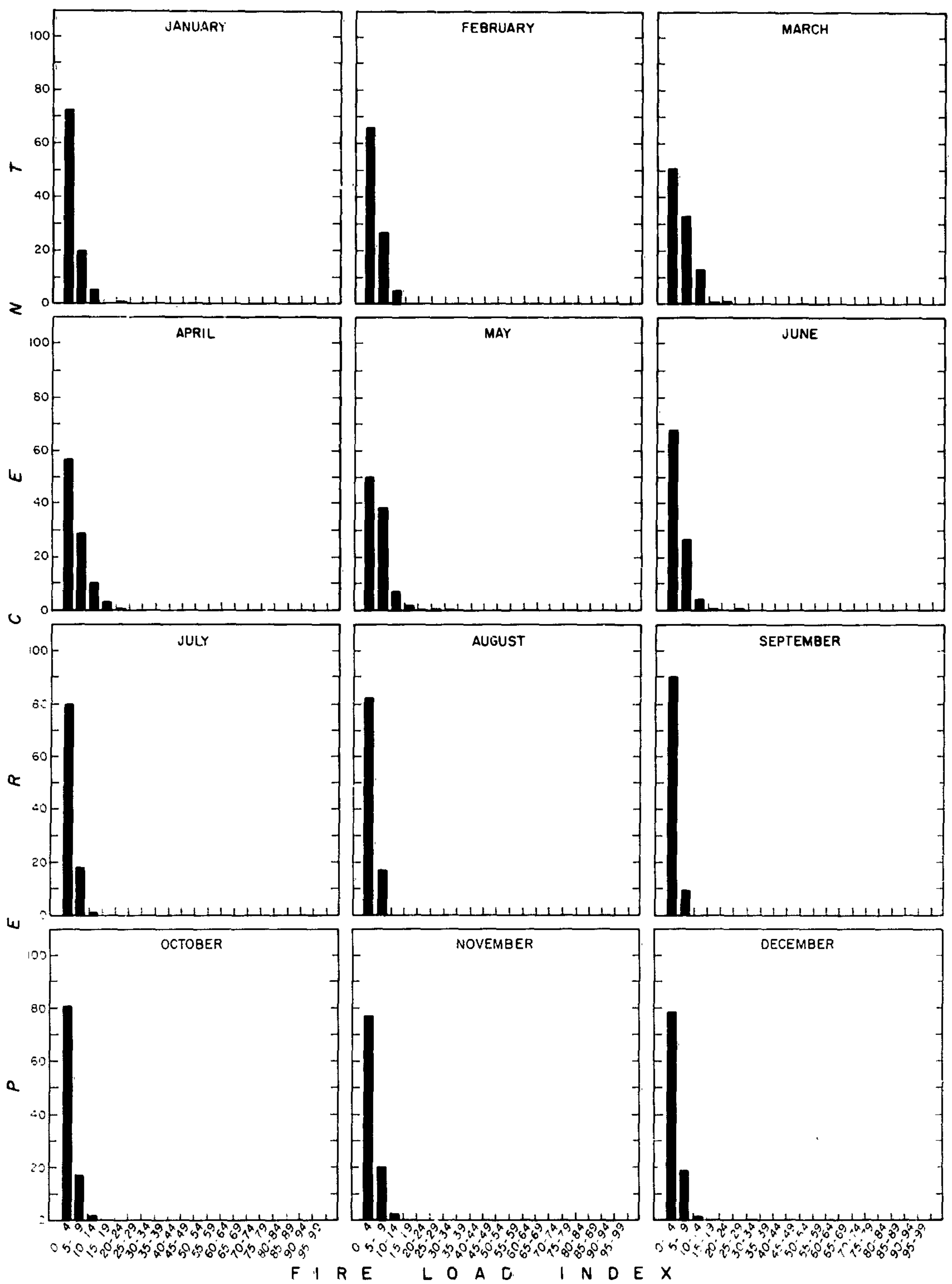
STATION 3813 MACON, GEORGIA



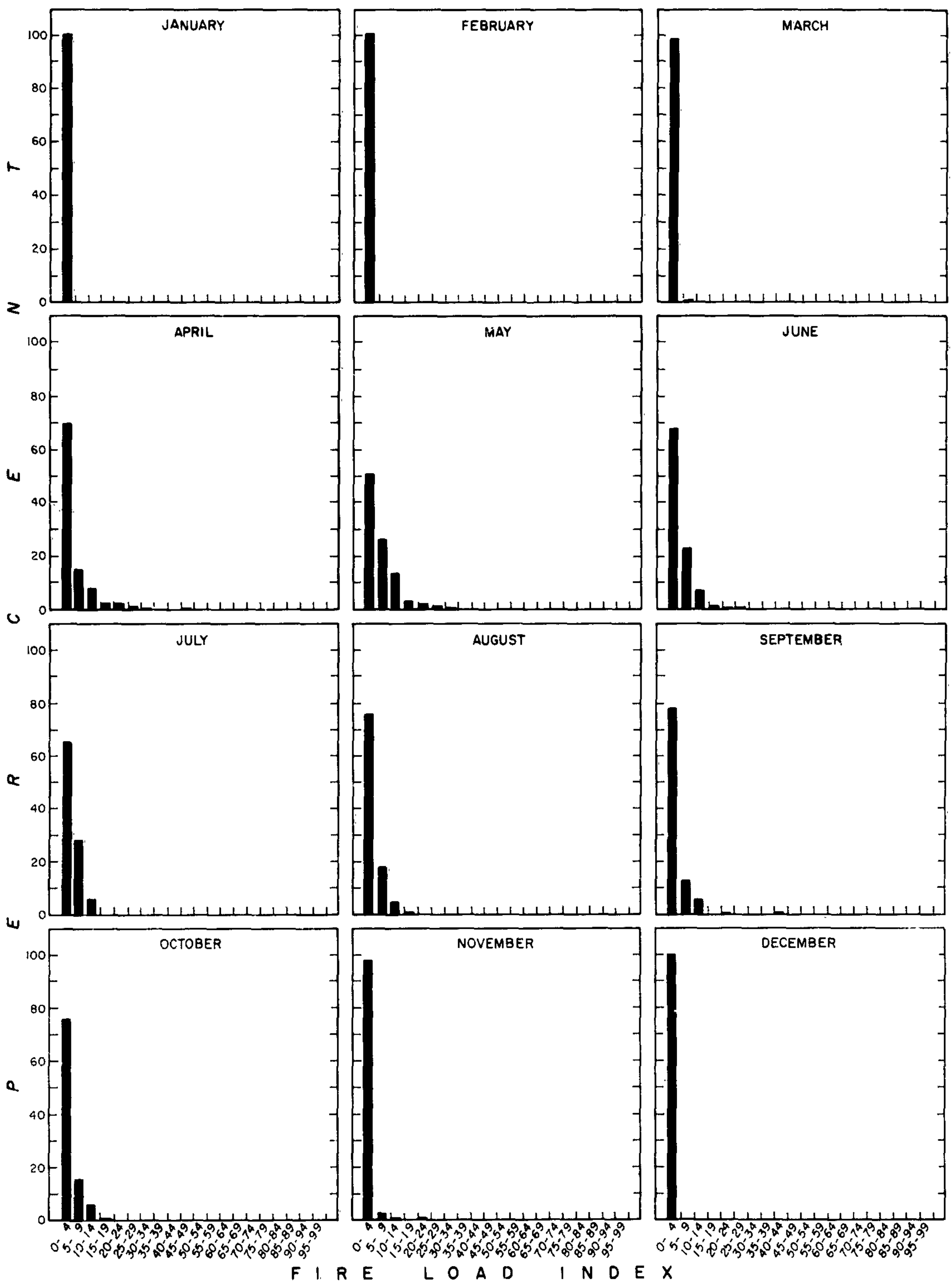
STATION 93805 TALLAHASSEE, FLORIDA



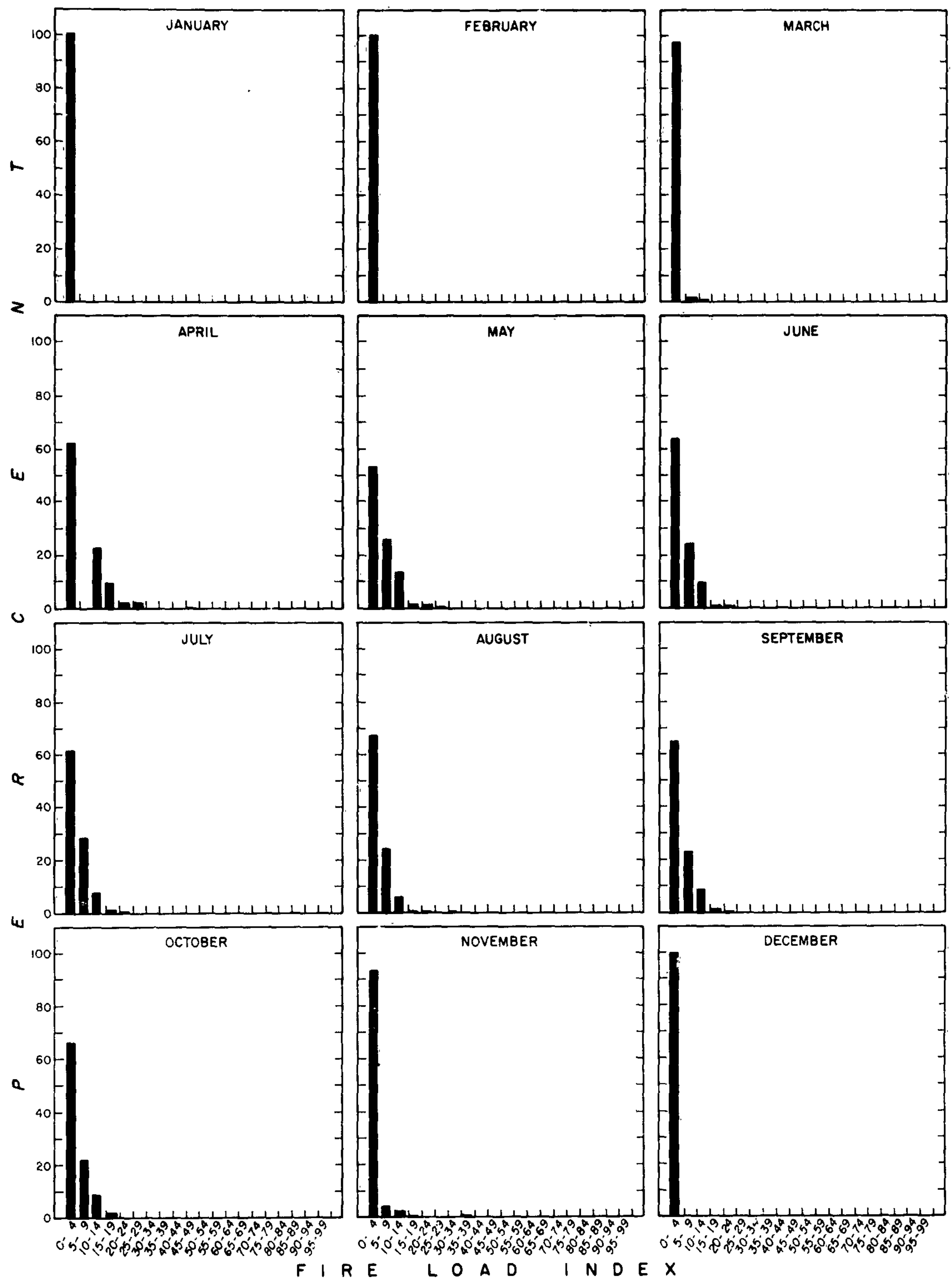
STATION 12841 ORLANDO, FLORIDA



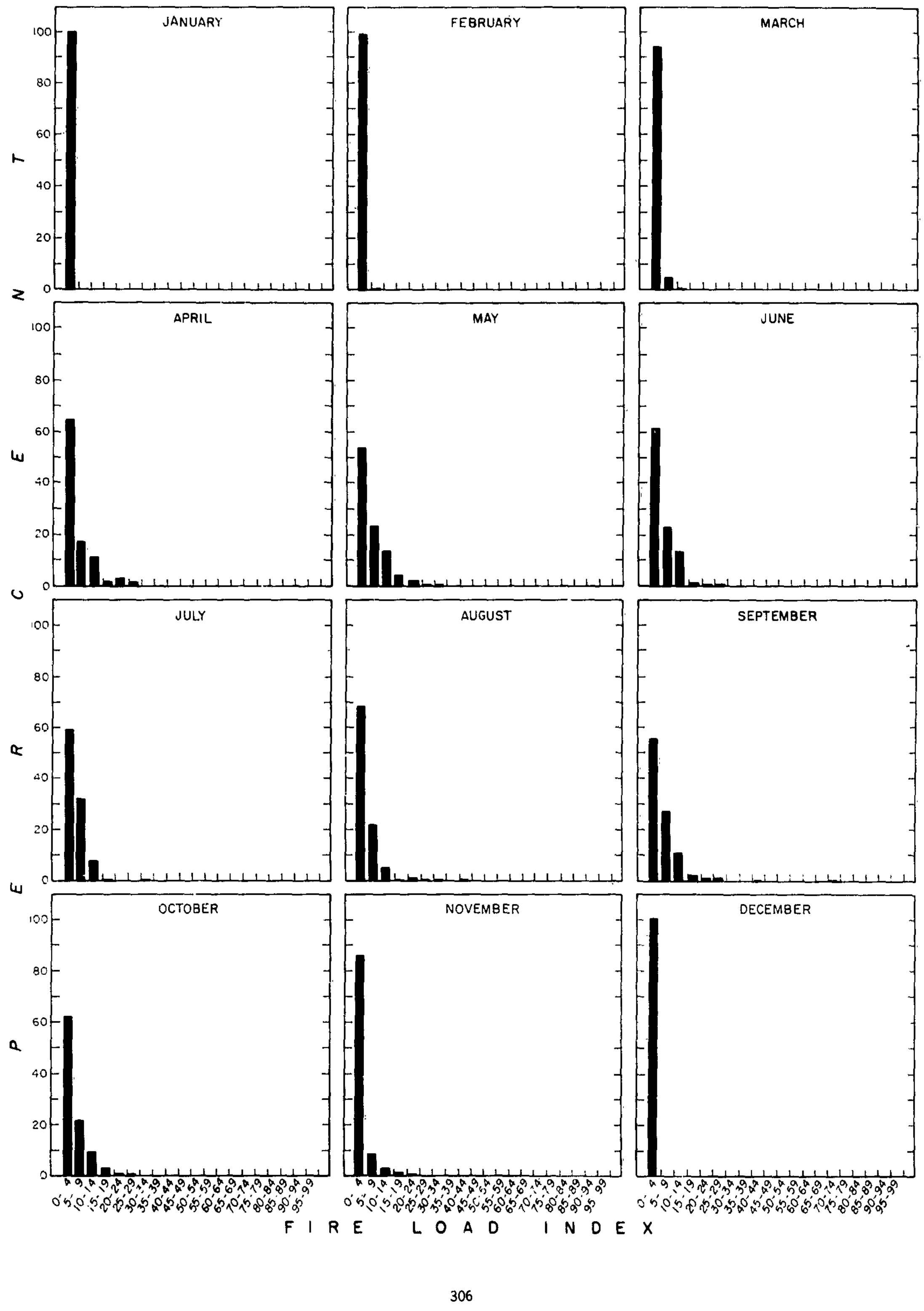
STATION 14918 INTERNATIONAL FALLS, MINNESOTA



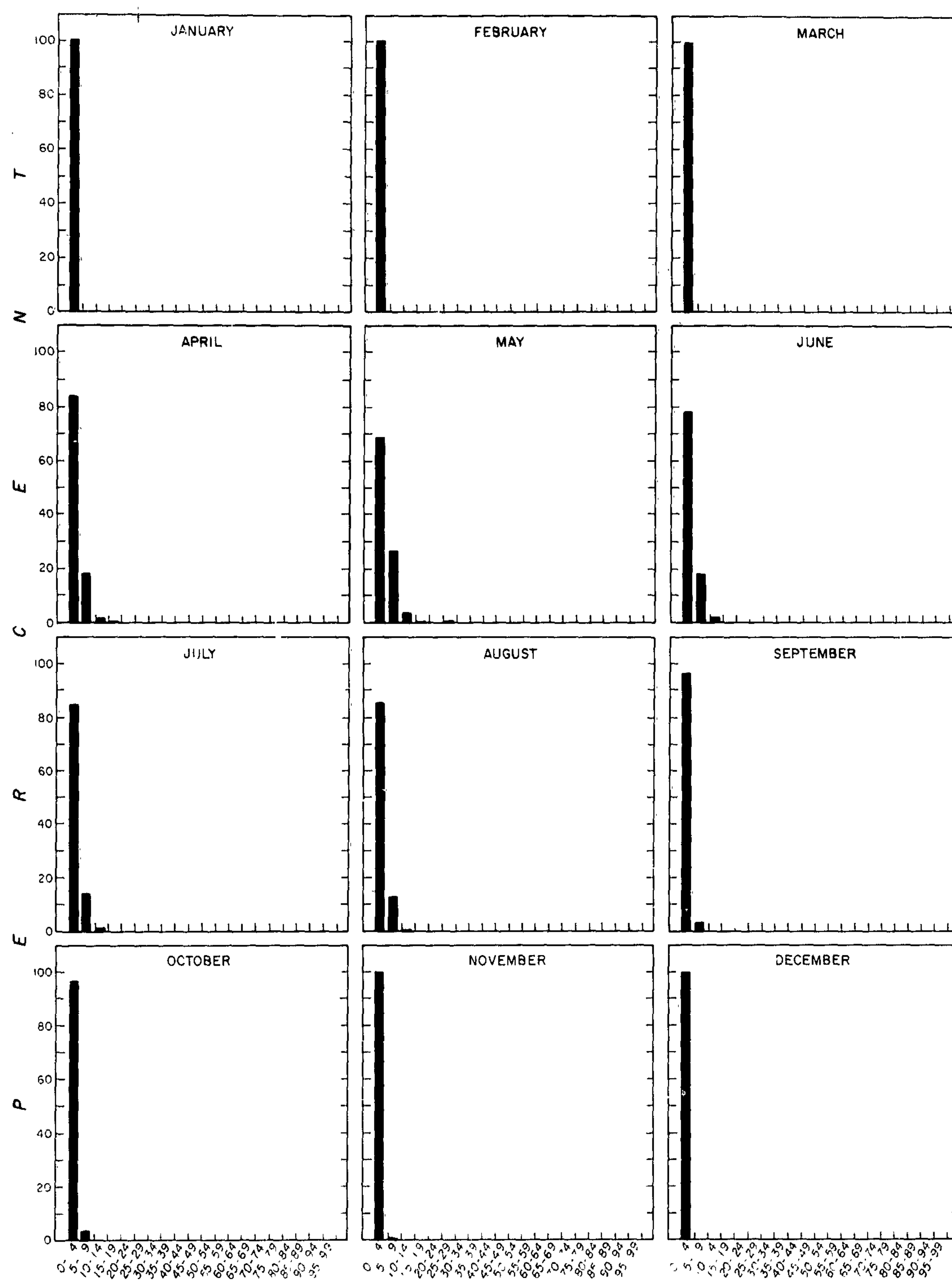
STATION 14991 EAU CLAIRE, WISCONSIN



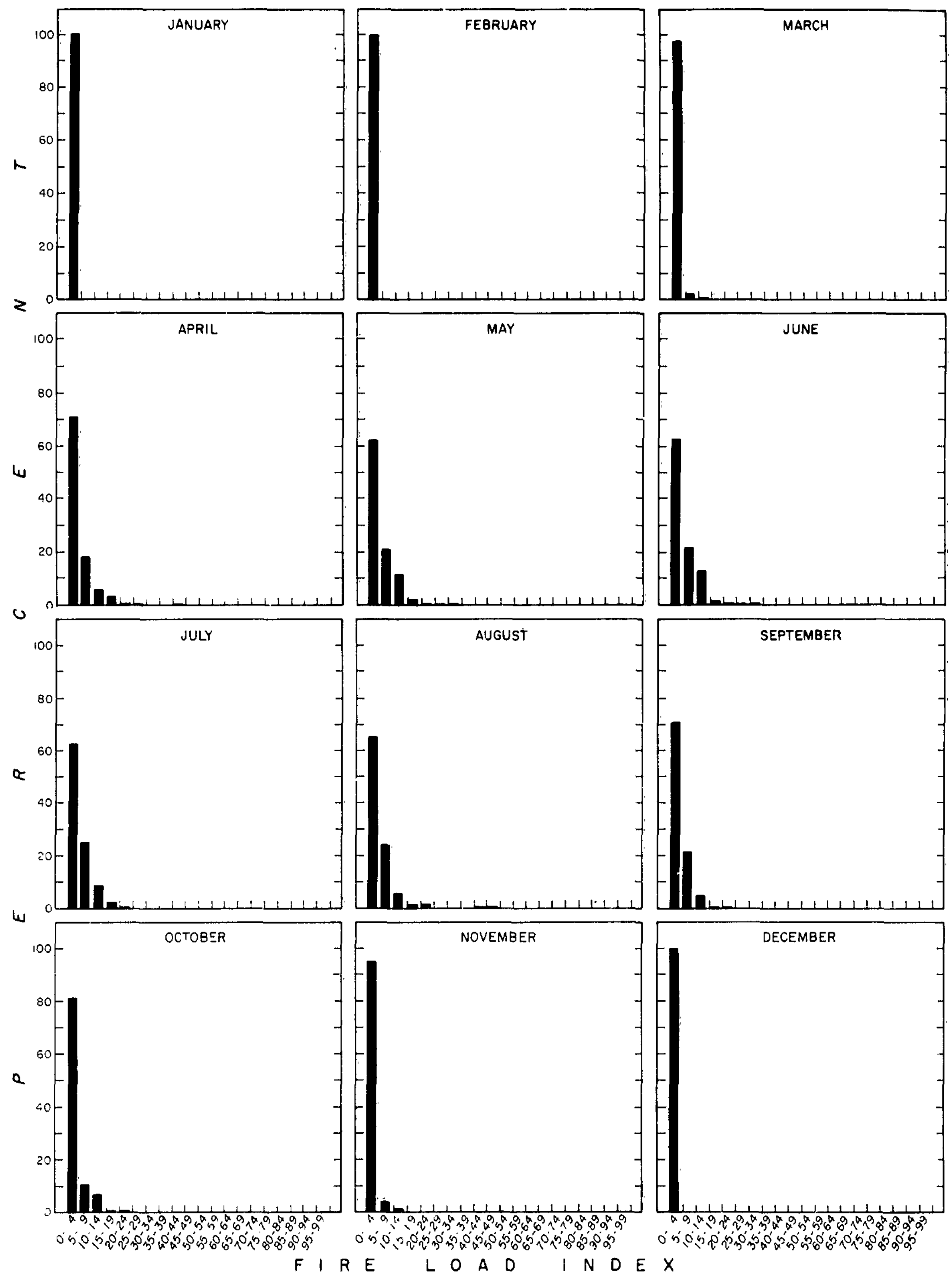
STATION 14837 MADISON, WISCONSIN



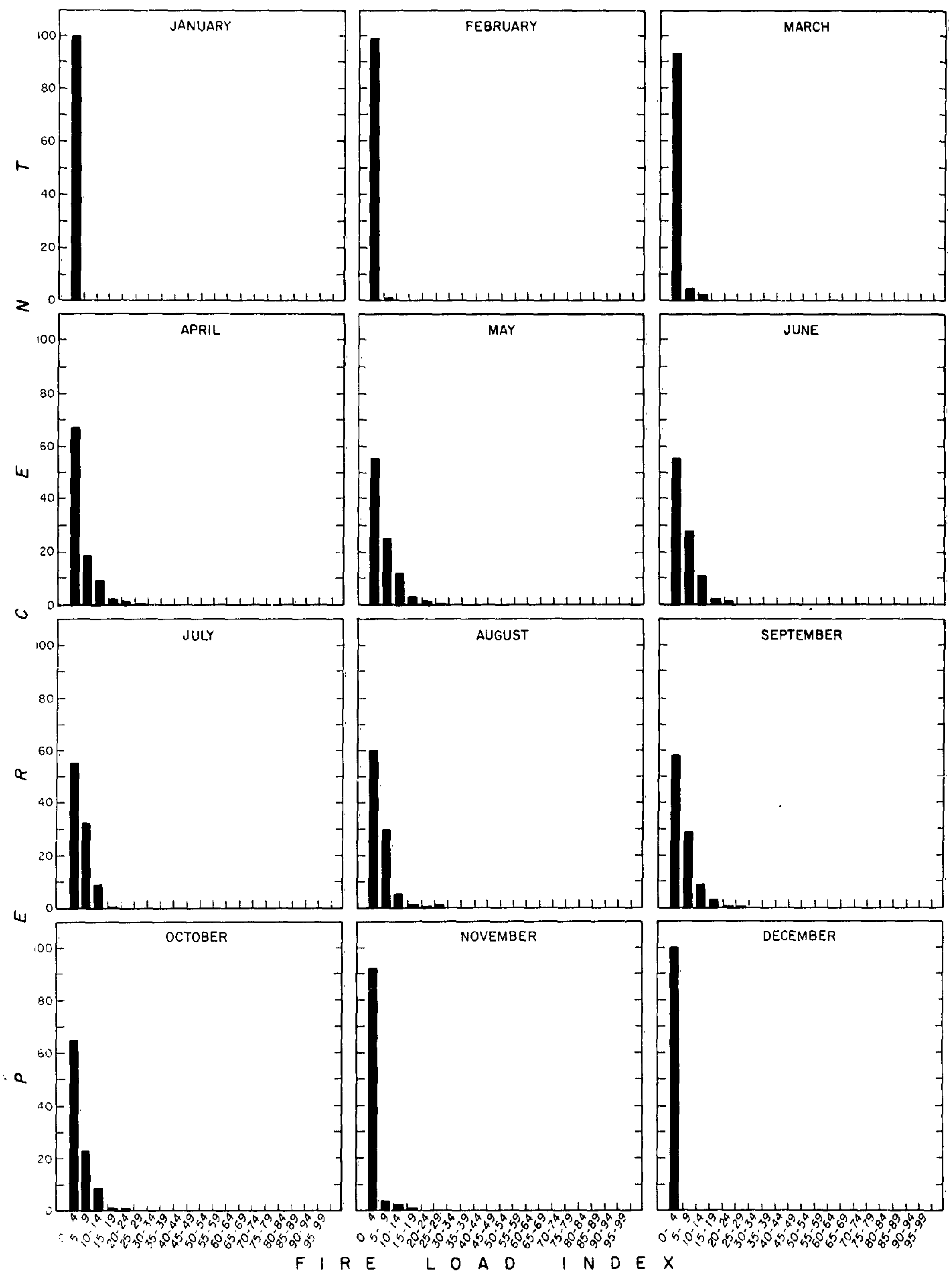
STATION 14847 SAULT STE. MARIE, MICHIGAN



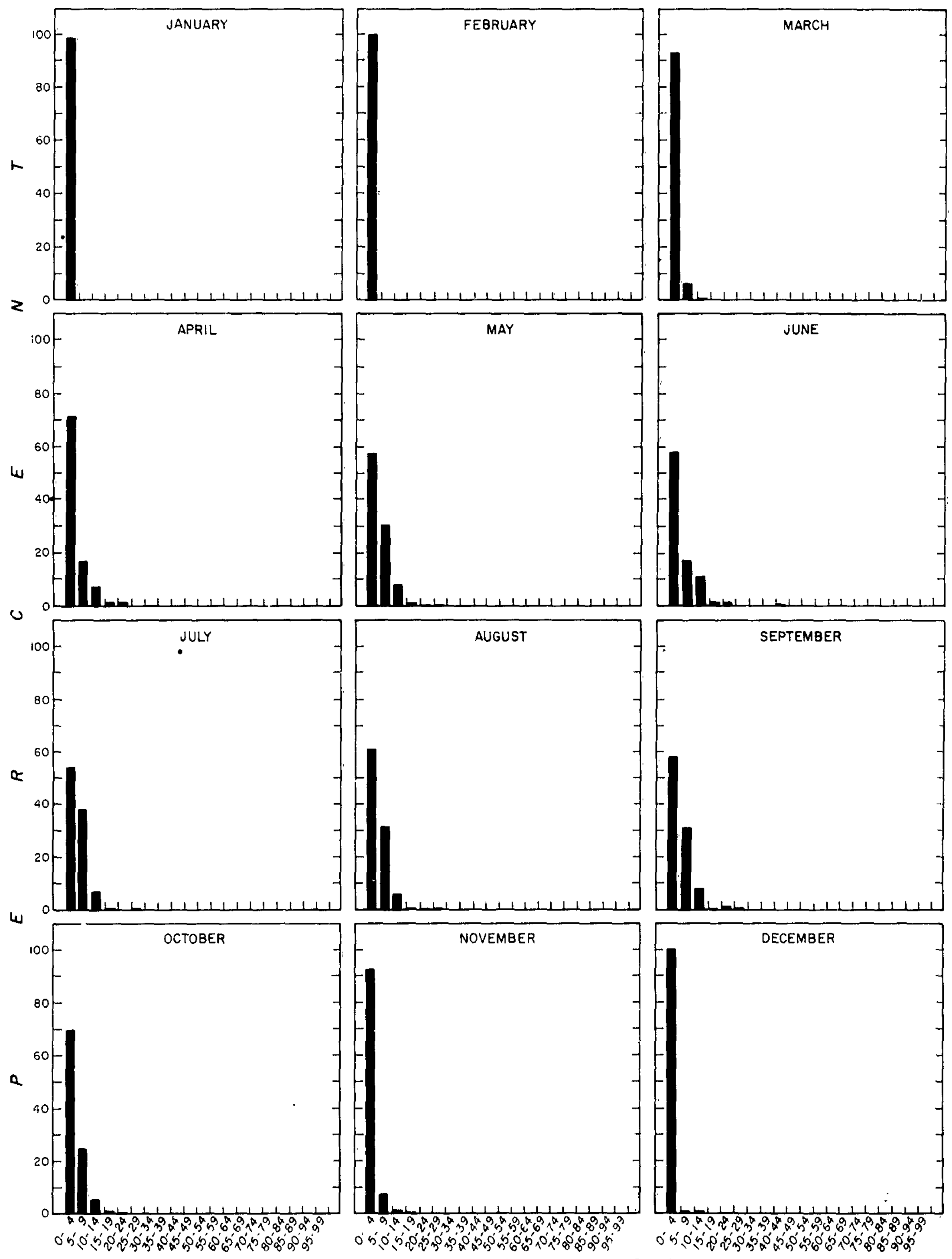
STATION 14850 TRAVERSE CITY, MICHIGAN



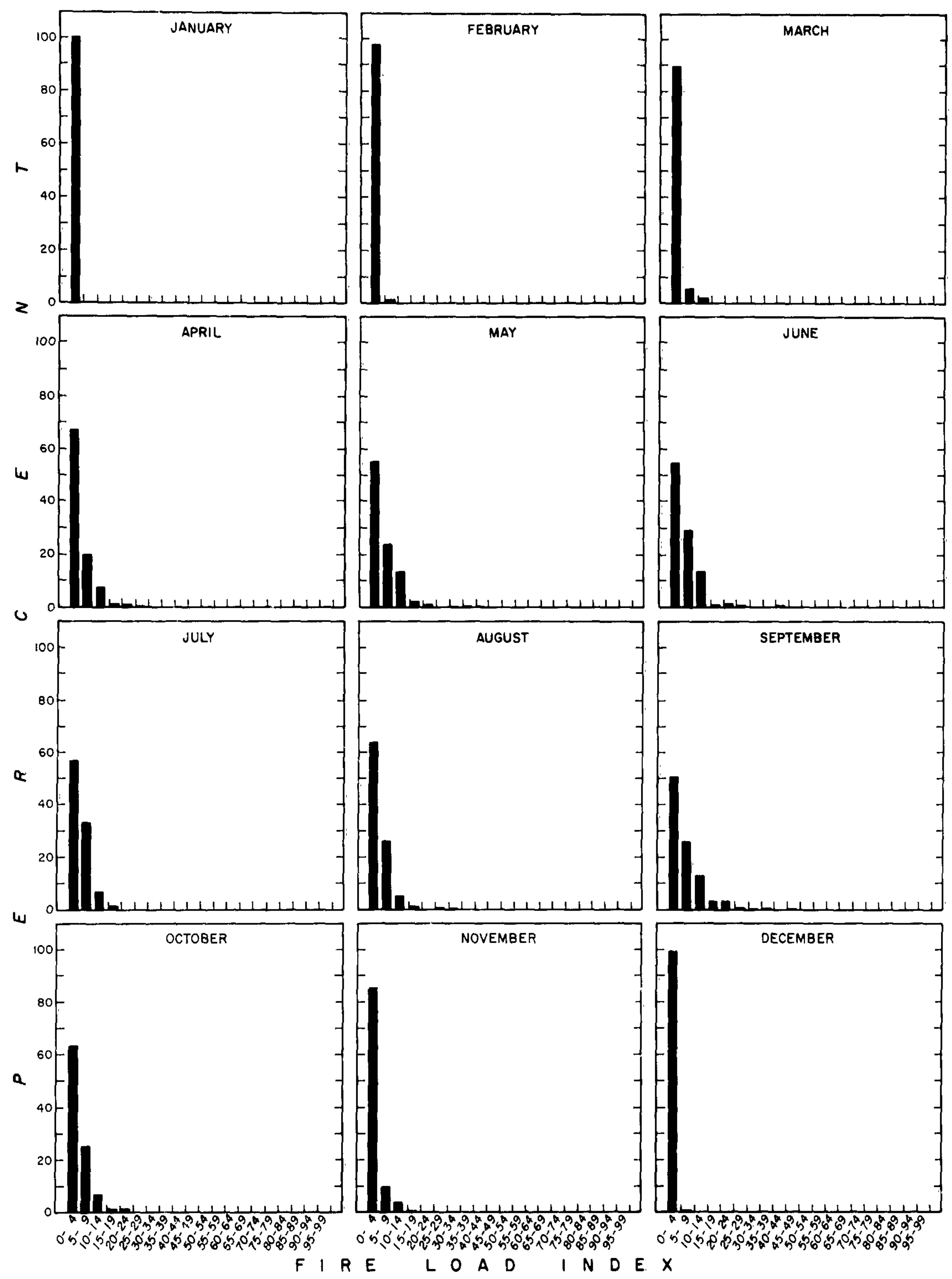
STATION 14830 GRAND RAPIDS, MICHIGAN



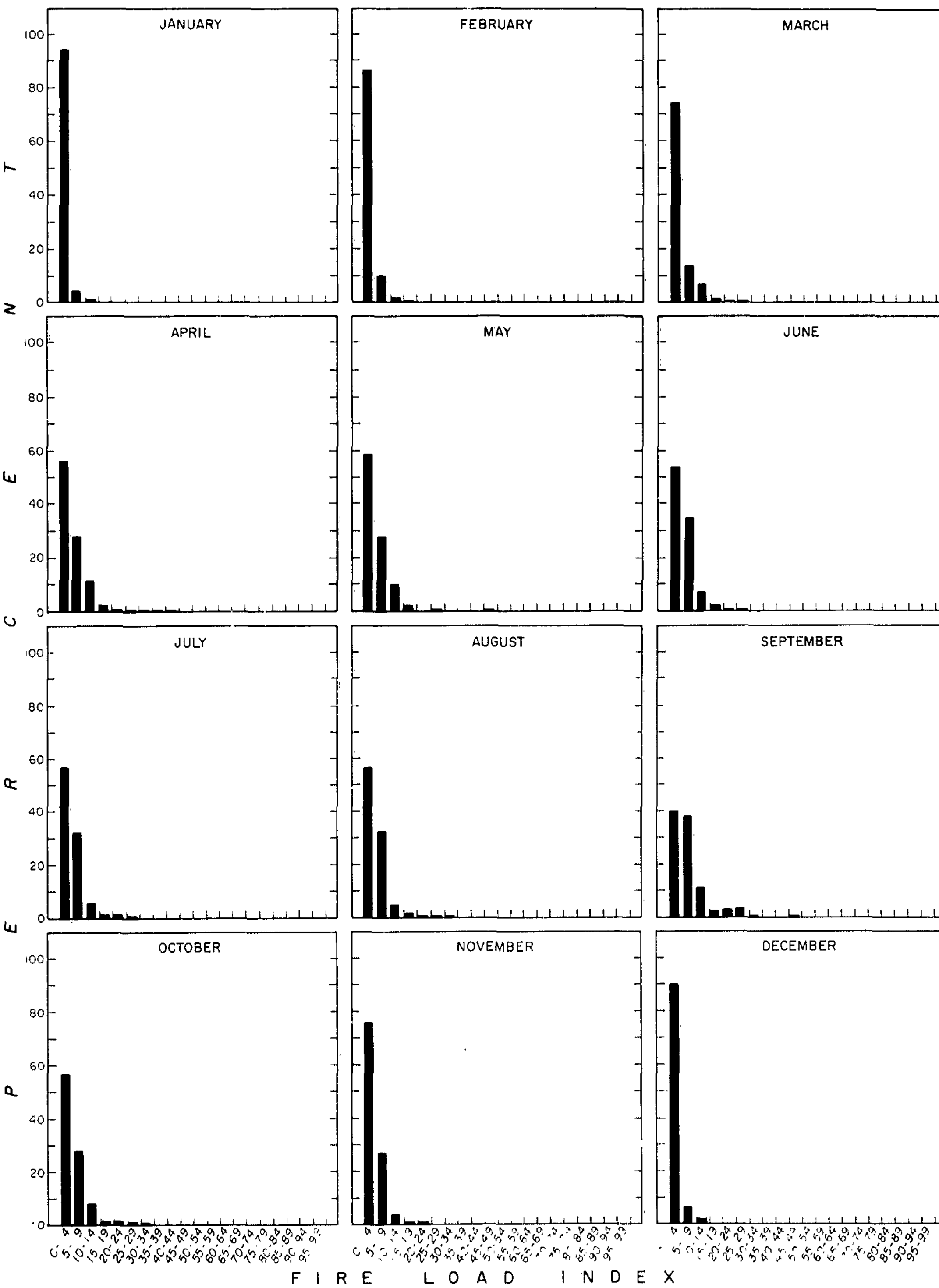
STATION 14822 DETROIT, MICHIGAN



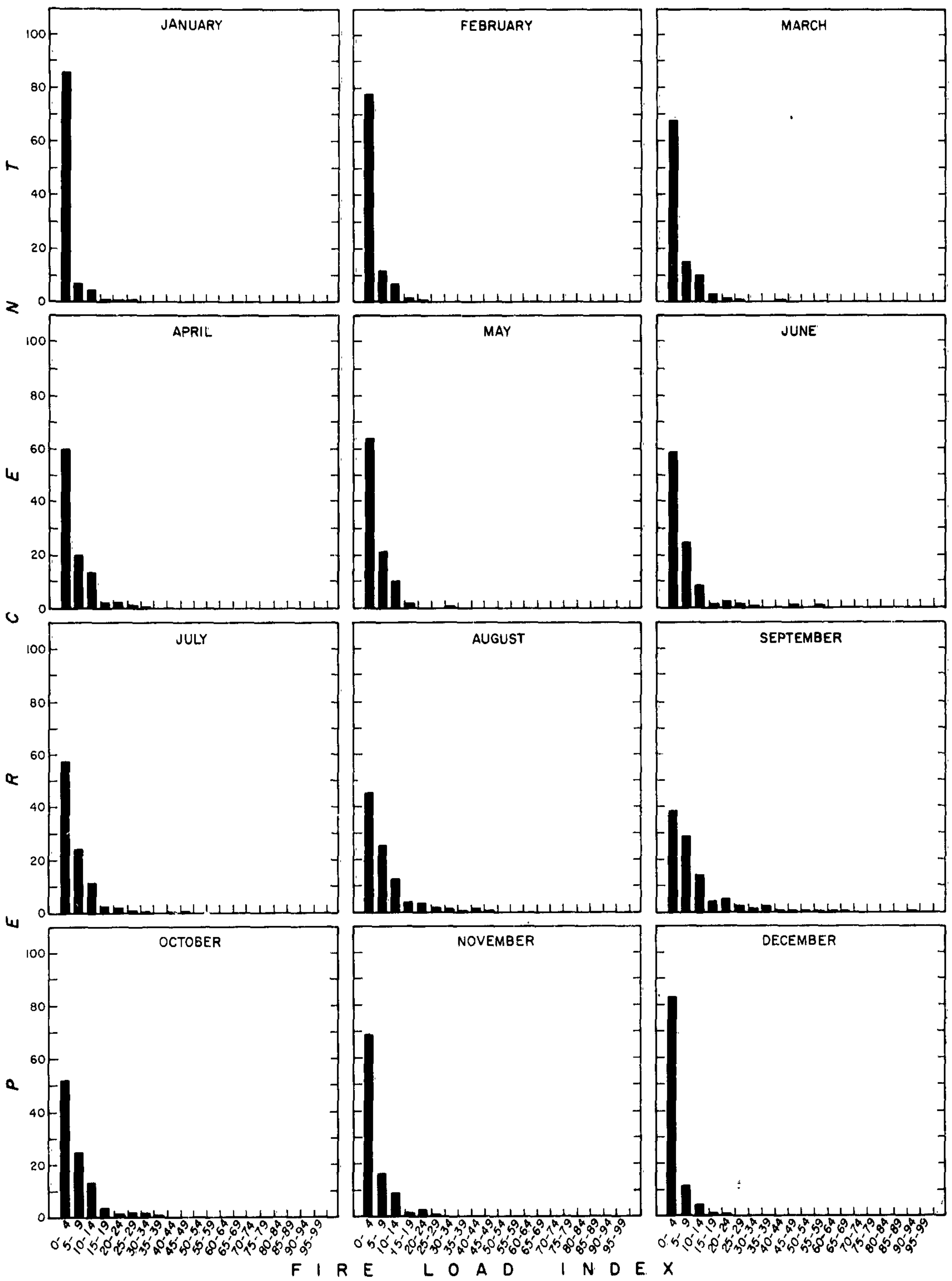
STATION 14819 CHICAGO (MIDWAY), ILLINOIS



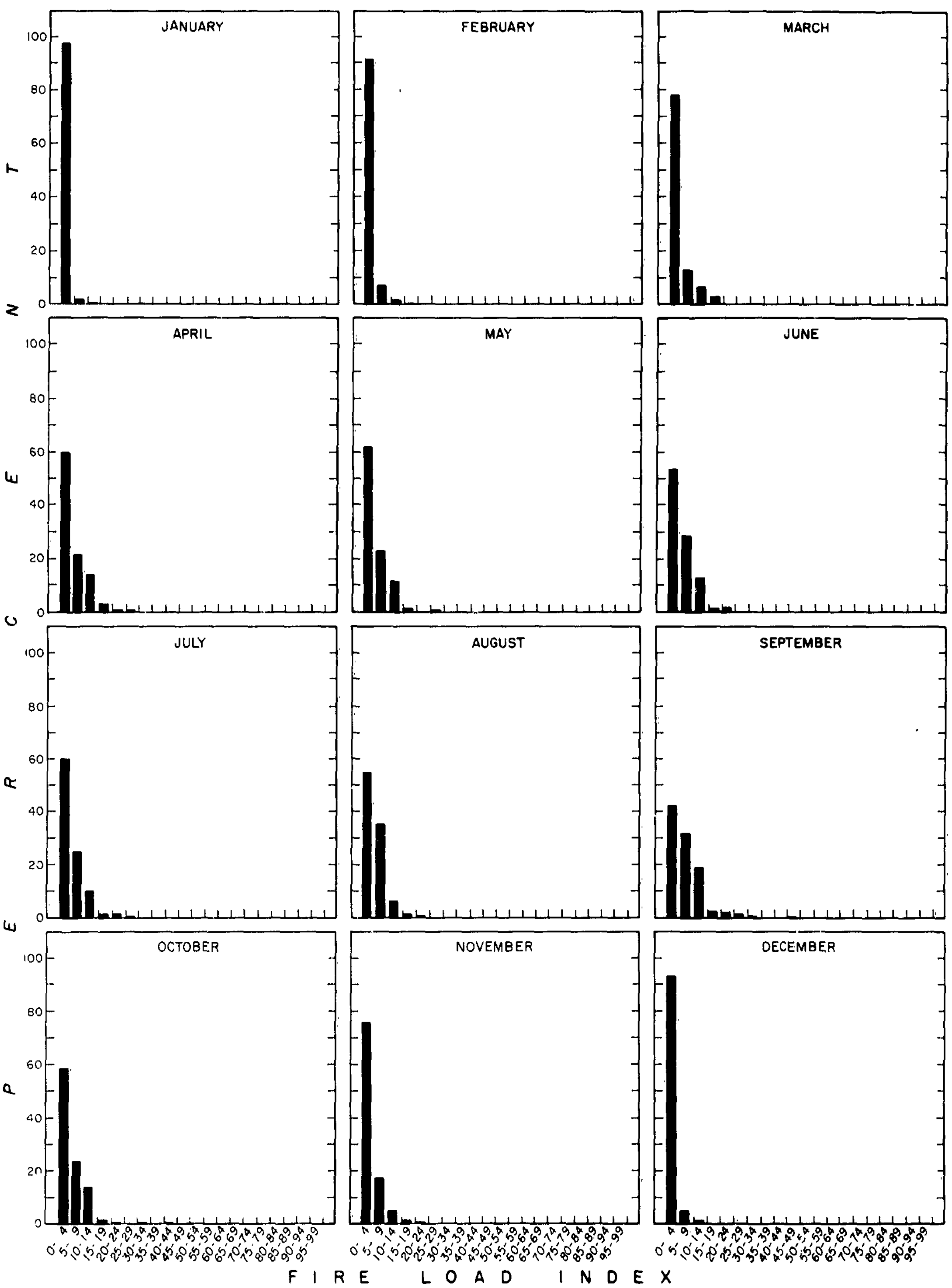
STATION 13994 ST. LOUIS, MISSOURI



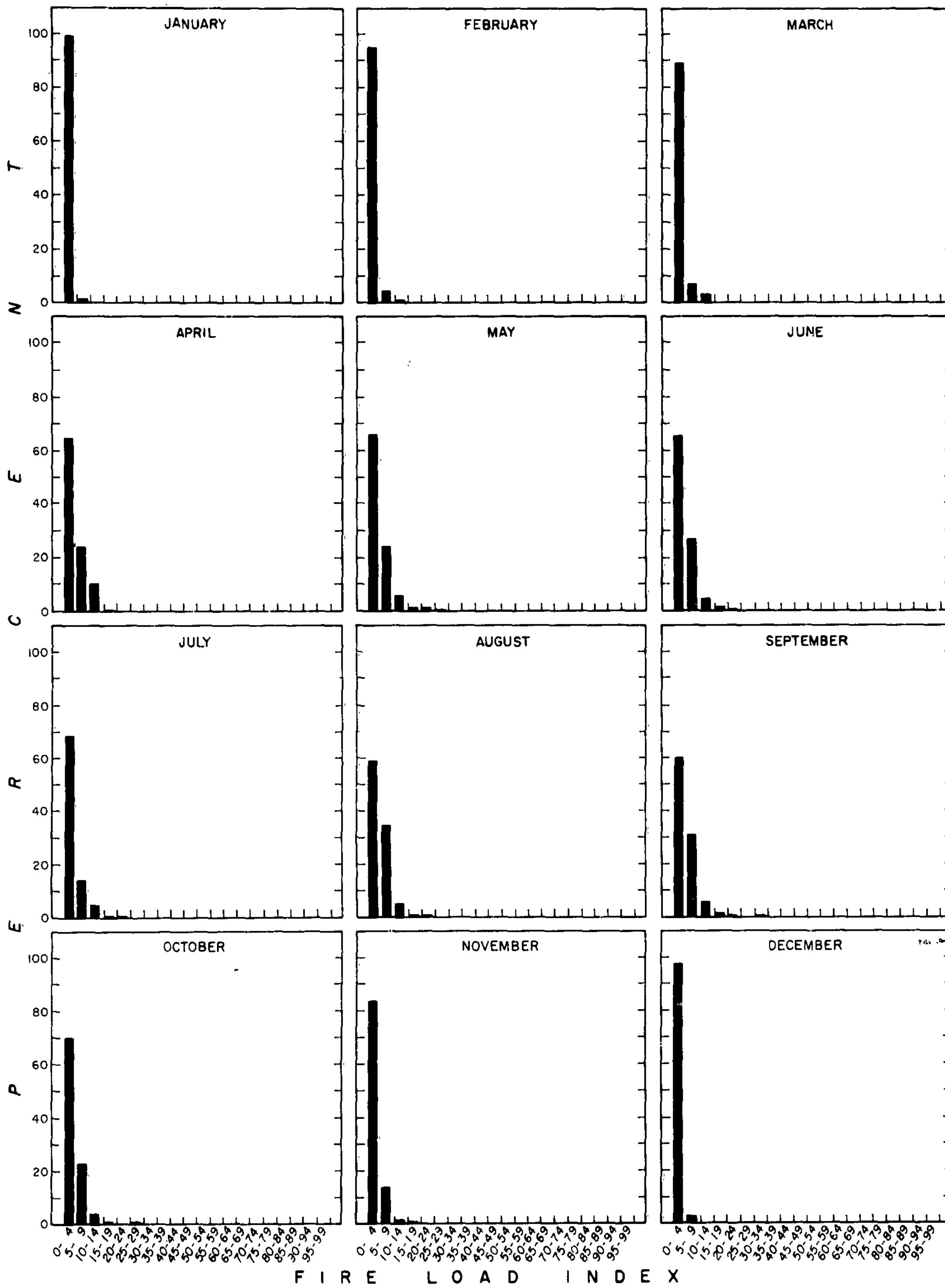
STATION 13995 SPRINGFIELD, MISSOURI



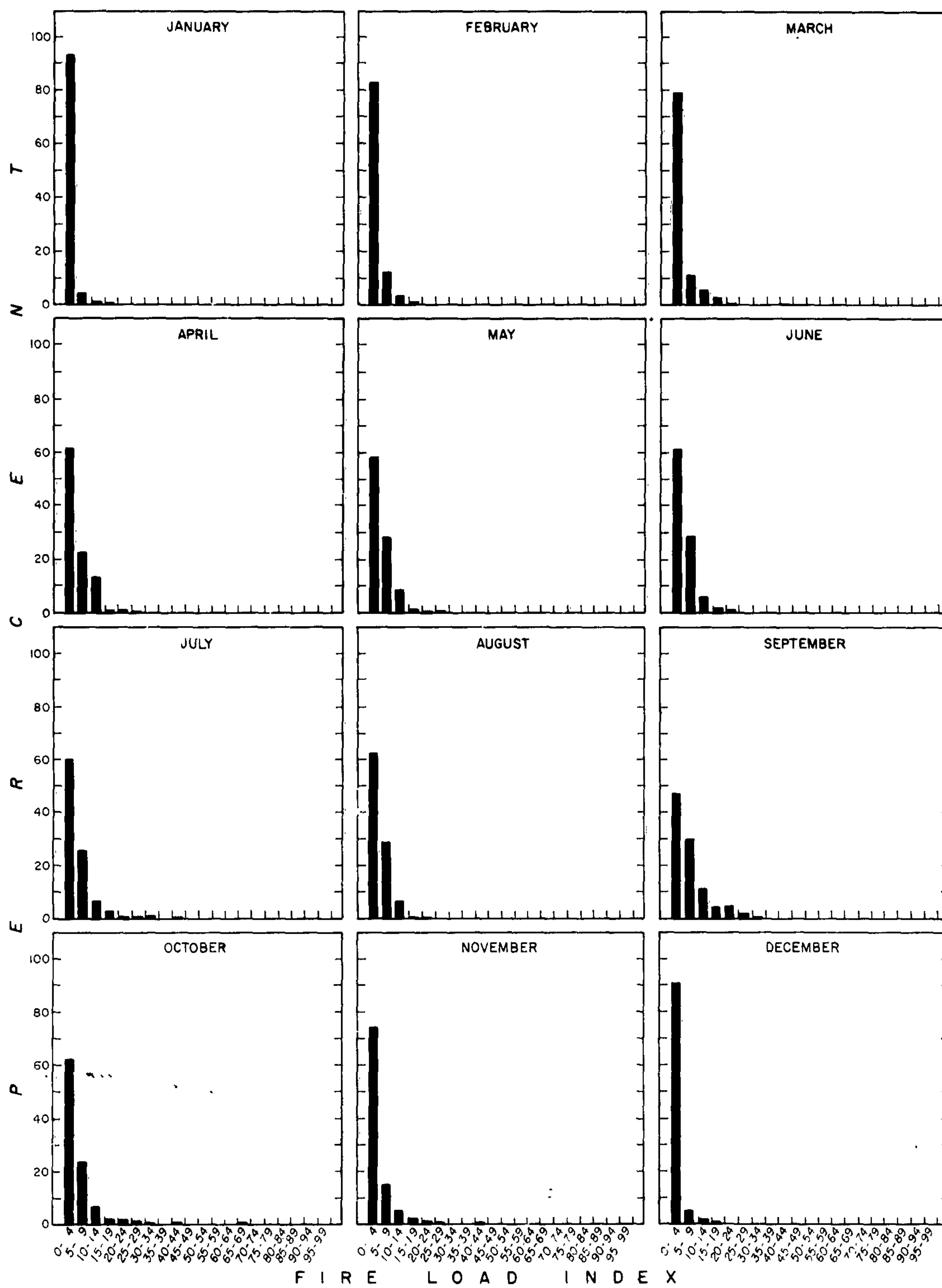
STATION 93817 EVANSVILLE, INDIANA



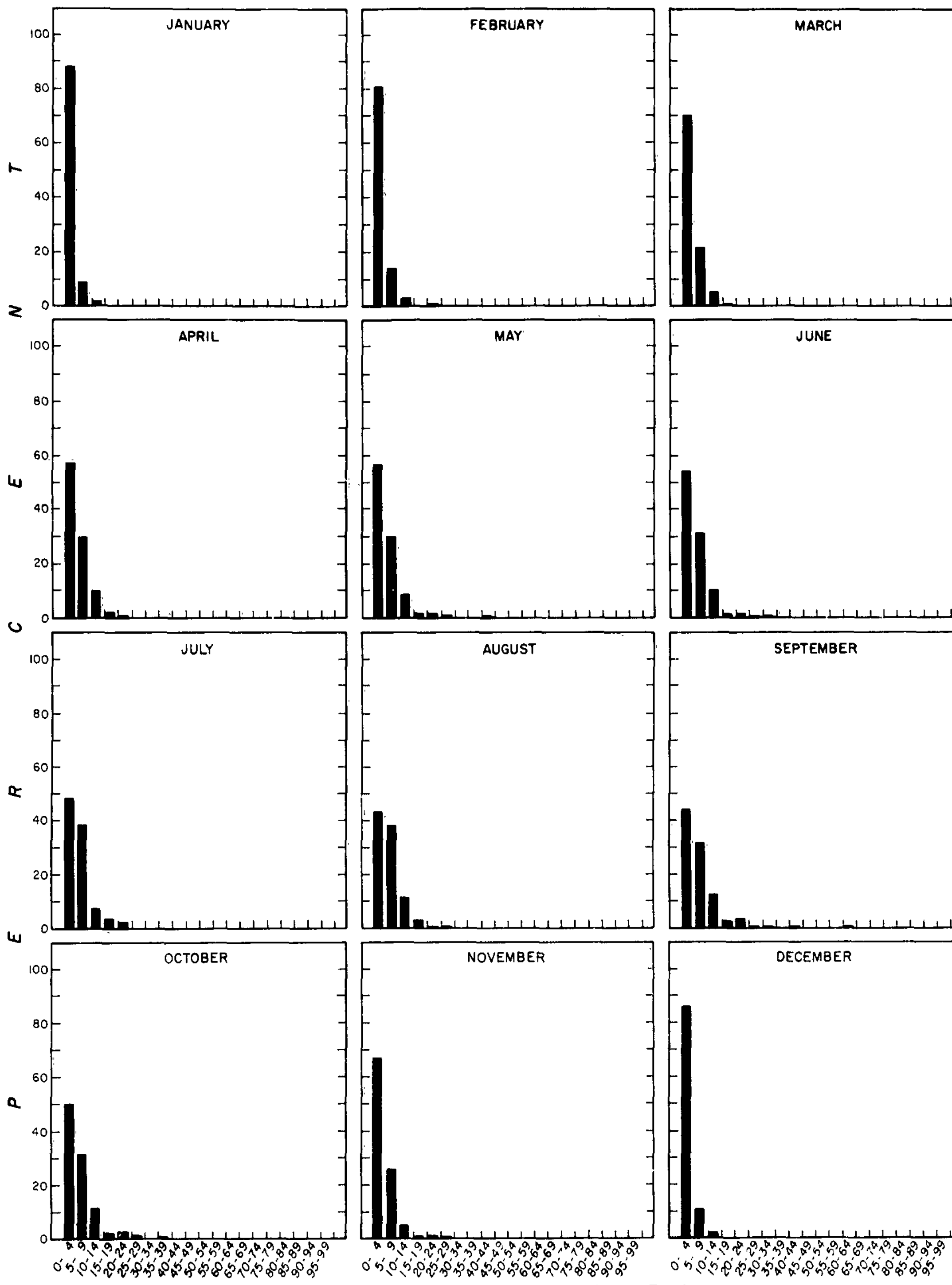
STATION 14821 COLUMBUS, OHIO



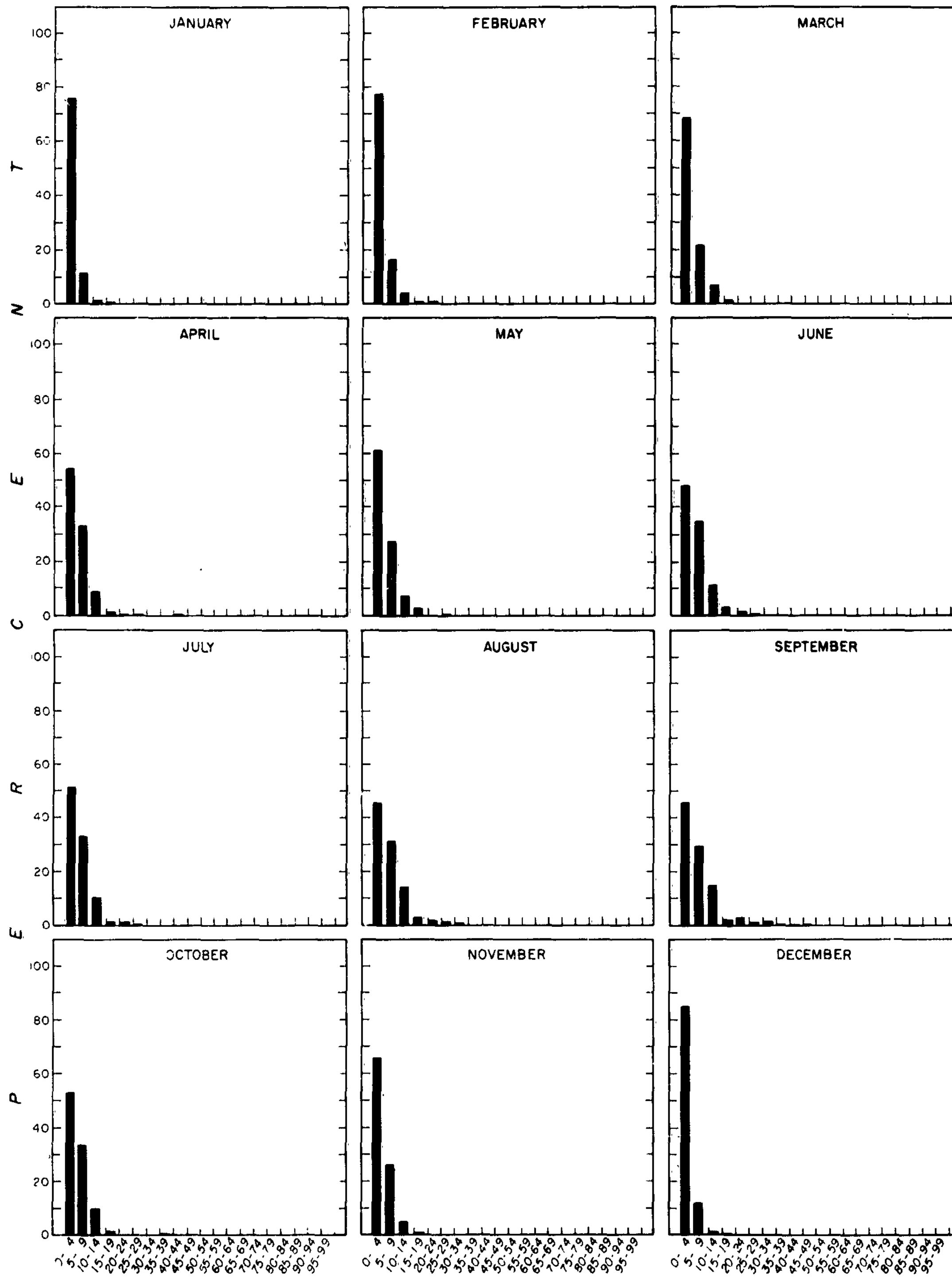
STATION 93820 LEXINGTON, KENTUCKY



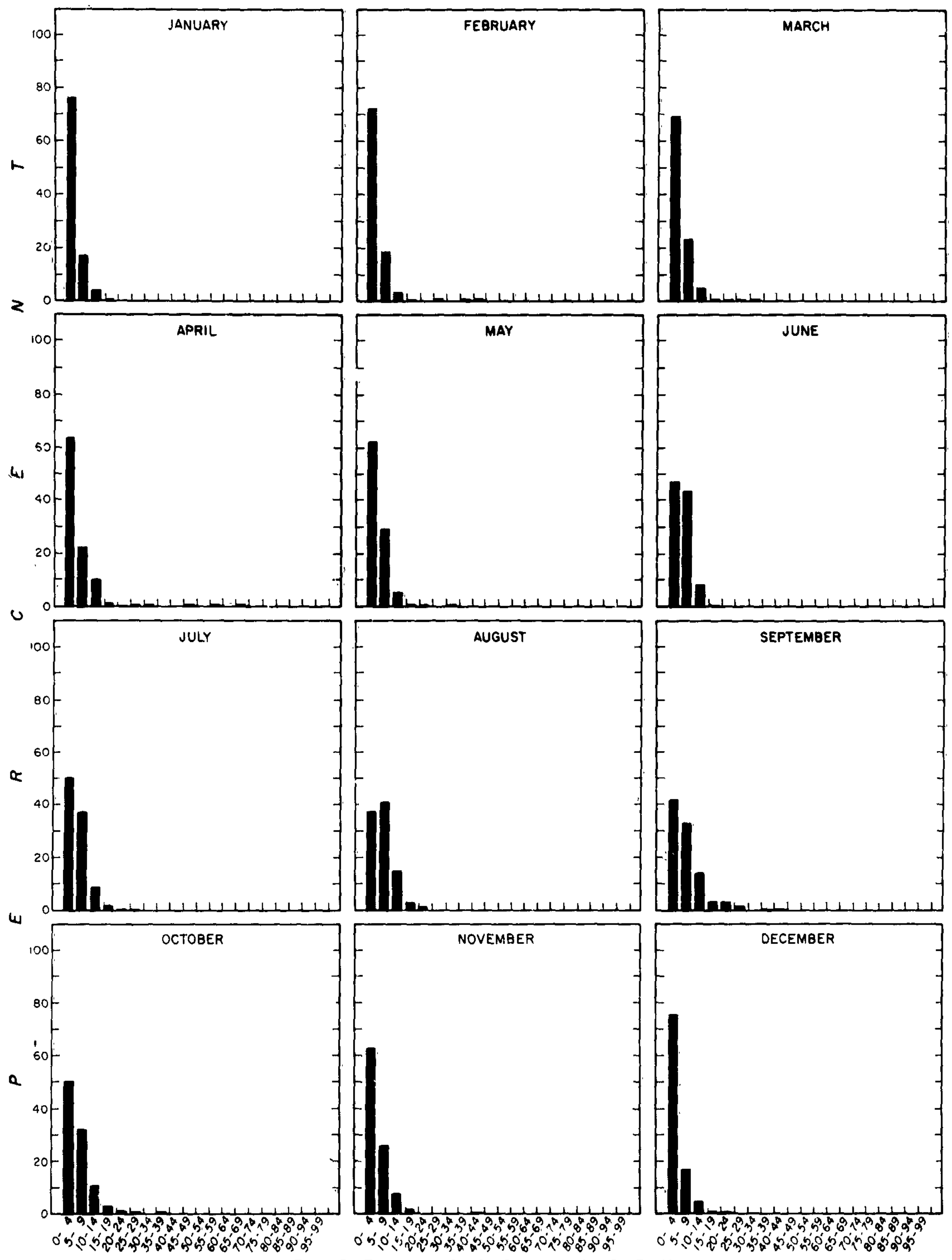
STATION 13893 MEMPHIS, TENNESSEE



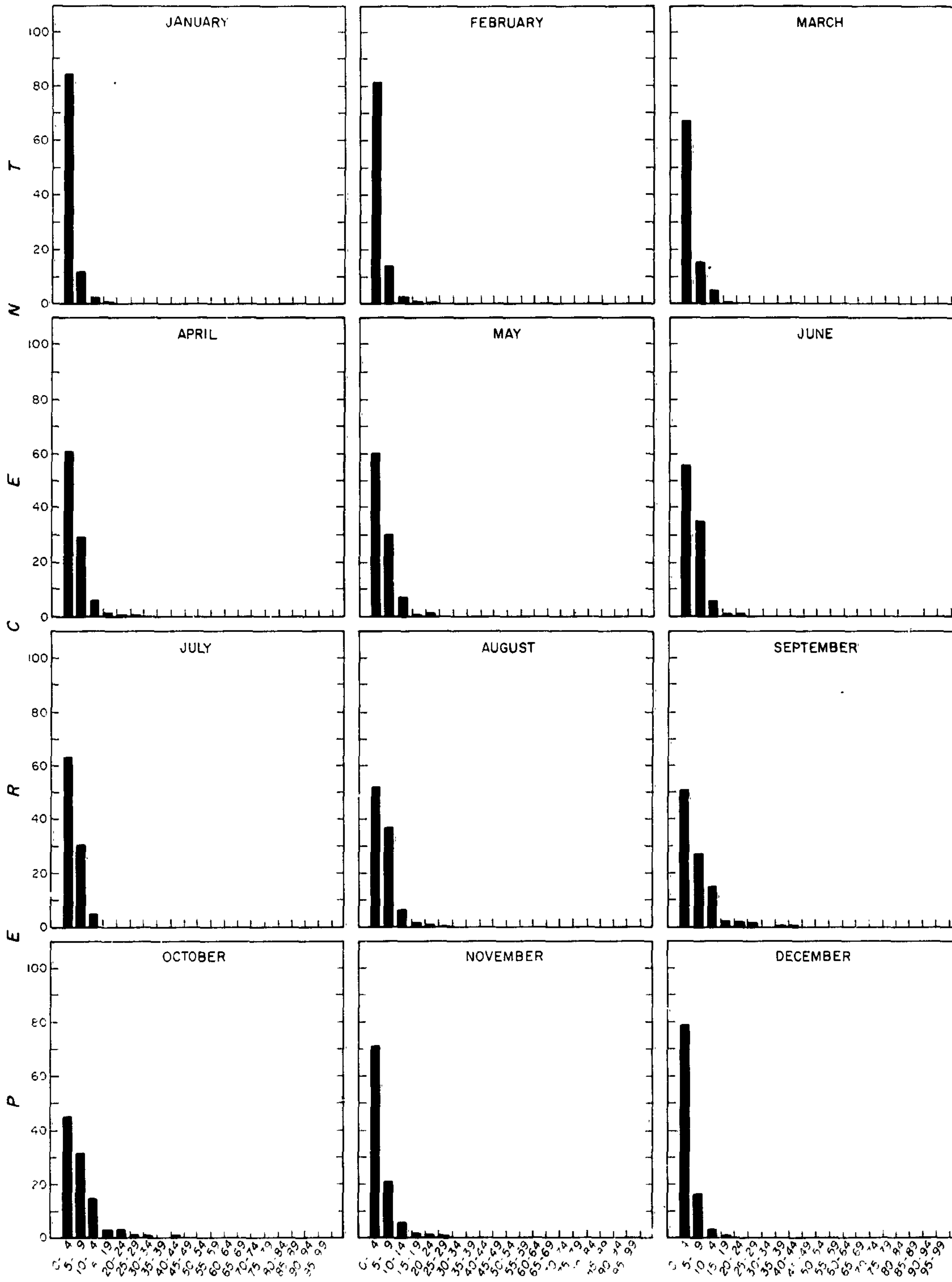
STATION 13963 LITTLE ROCK, ARKANSAS



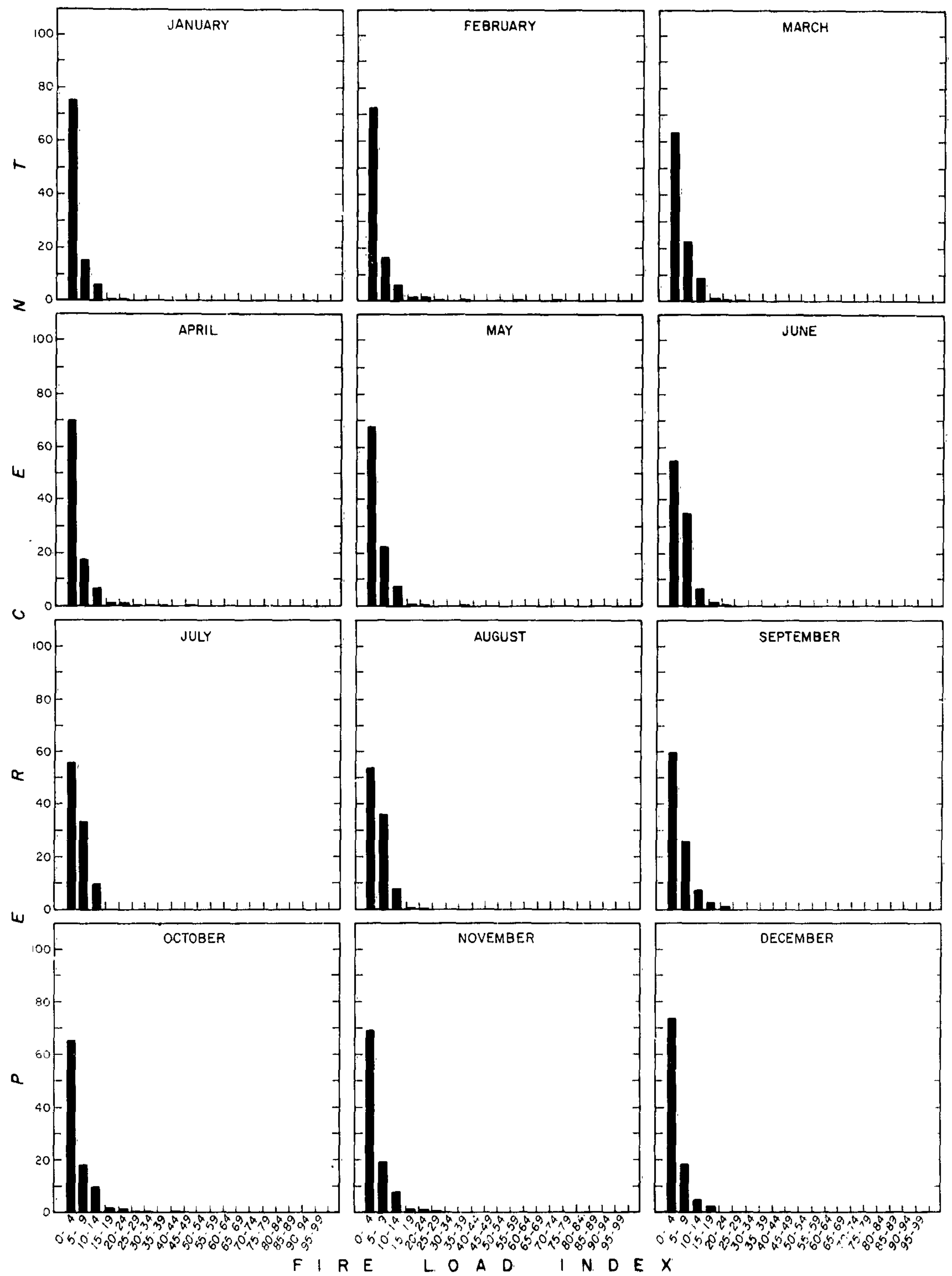
STATION 13957 SHREVEPORT, LOUISIANA



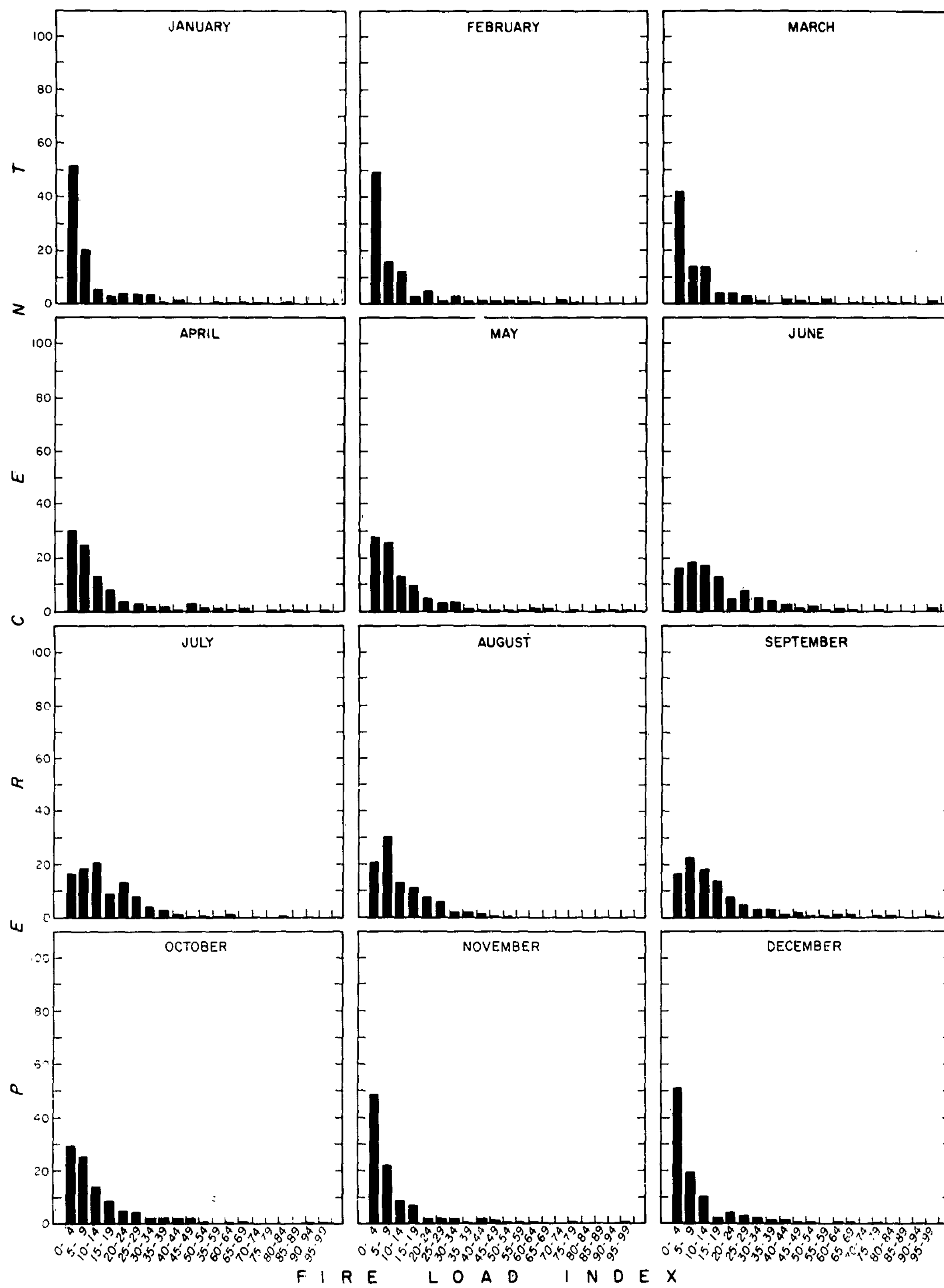
STATION 13956 JACKSON, MISSISSIPPI



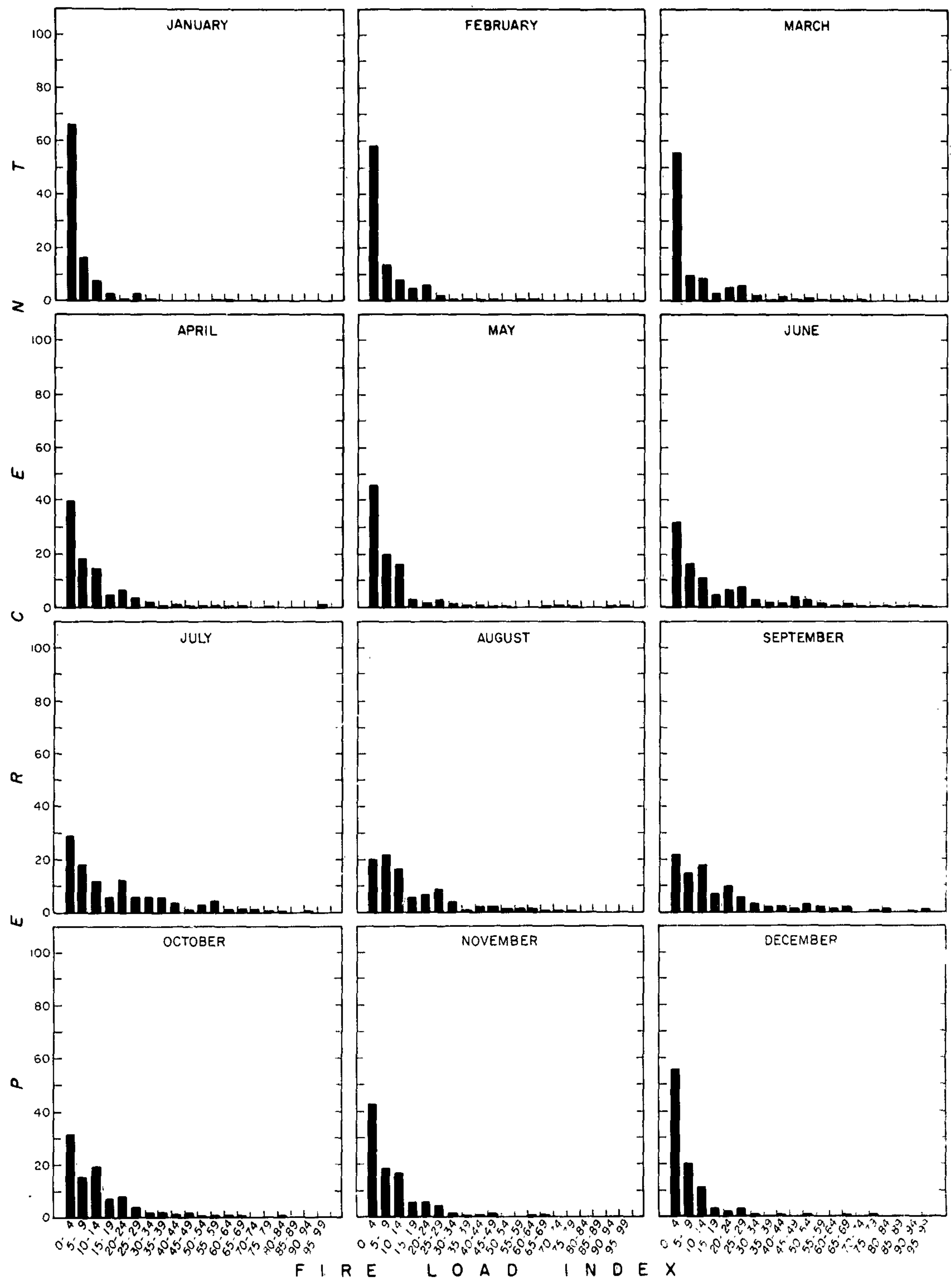
STATION 12918 HOUSTON, TEXAS



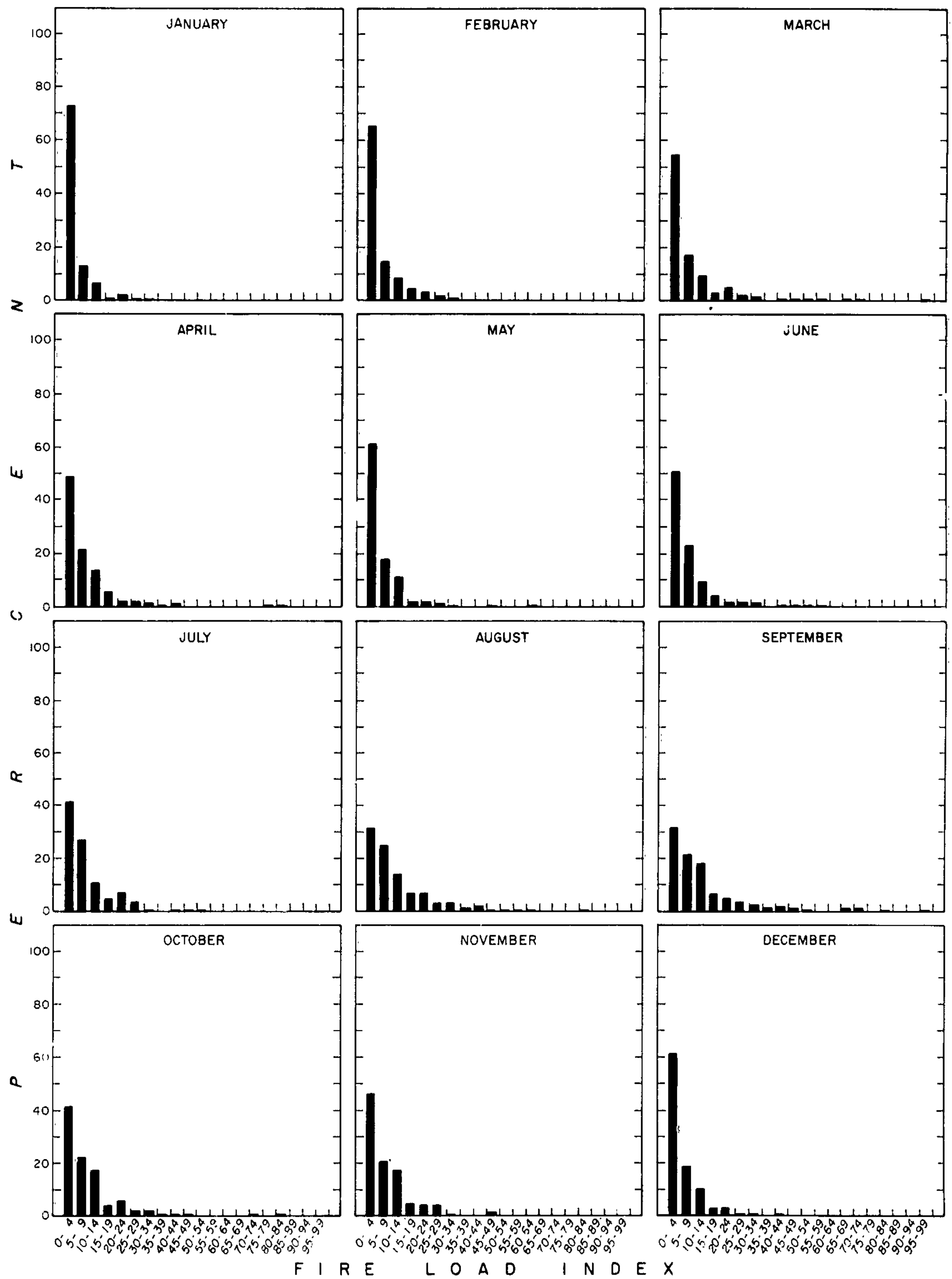
STATION 93058 PUEBLO, COLORADO



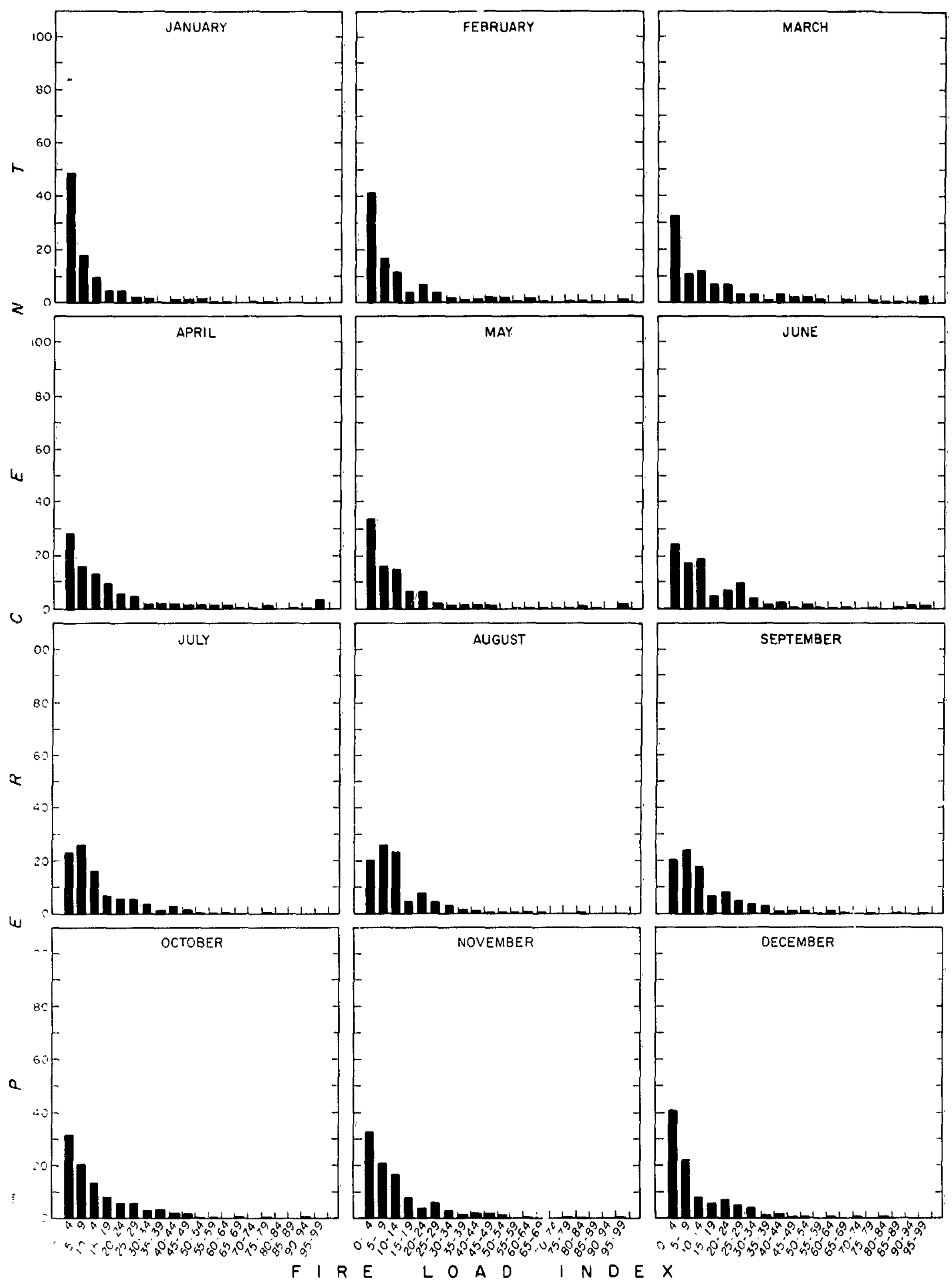
STATION 13985 DODGE CITY, KANSAS



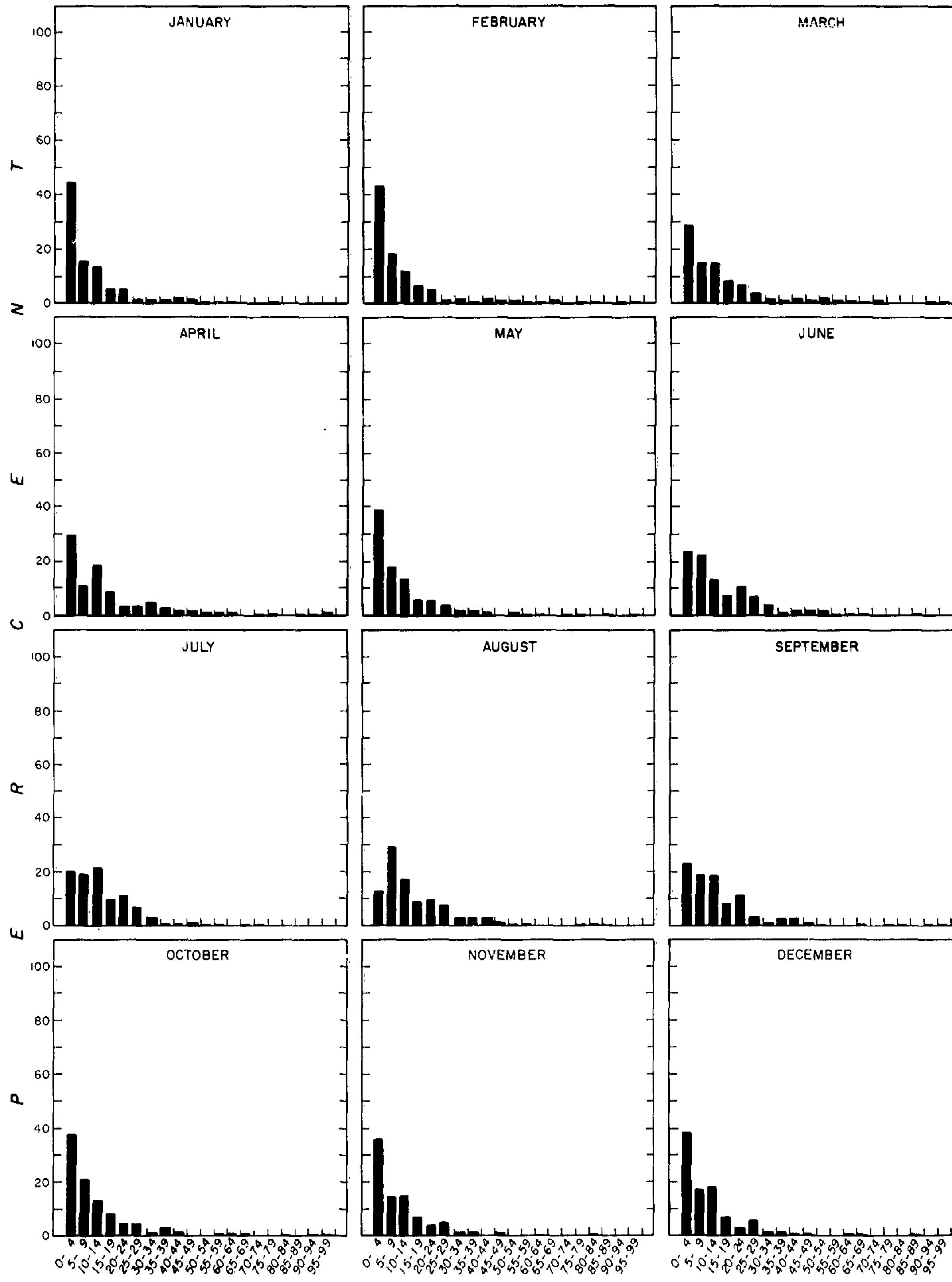
STATION 13967 OKLAHOMA CITY, OKLAHOMA



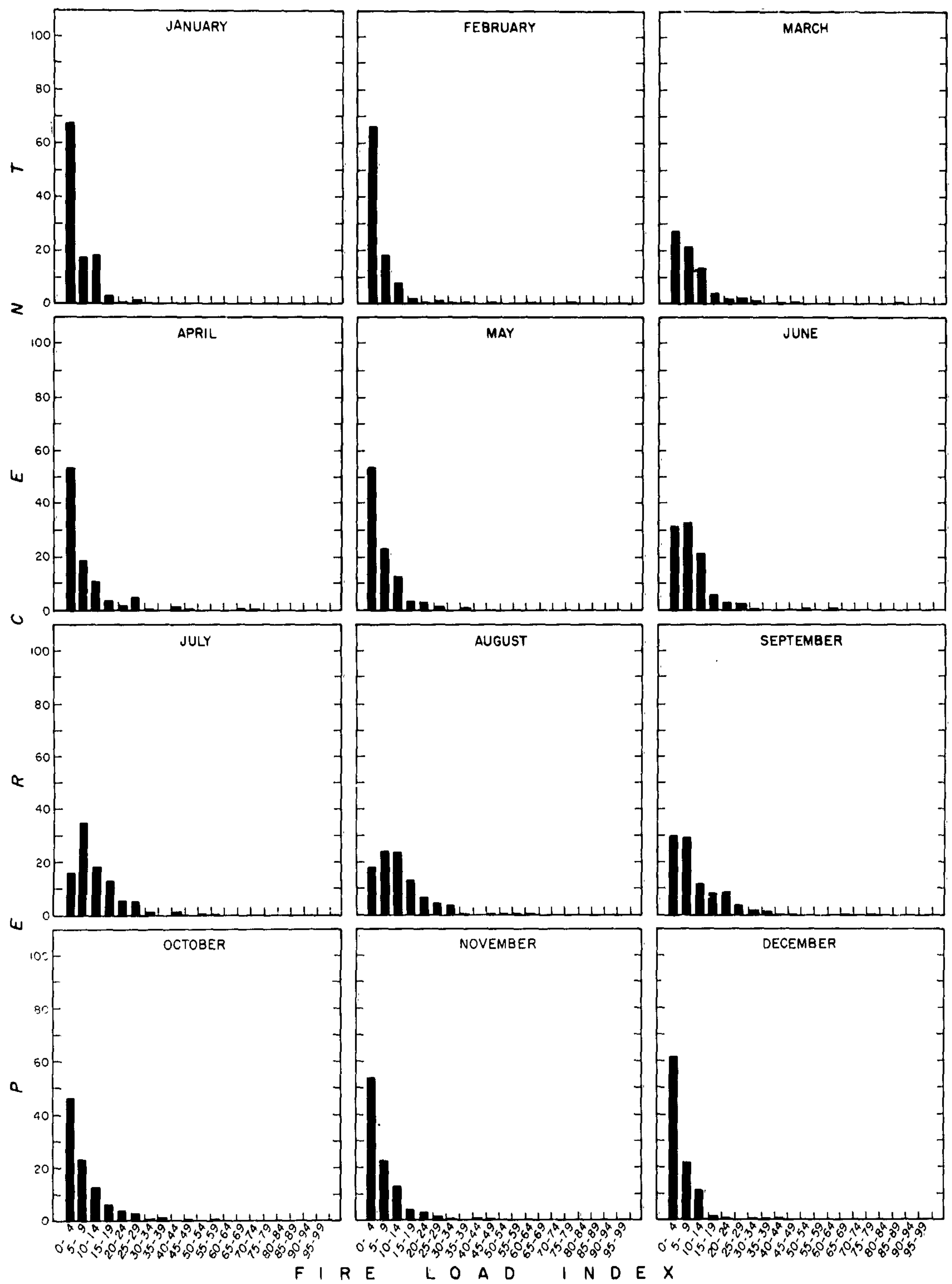
STATION 23047 AMARILLO, TEXAS



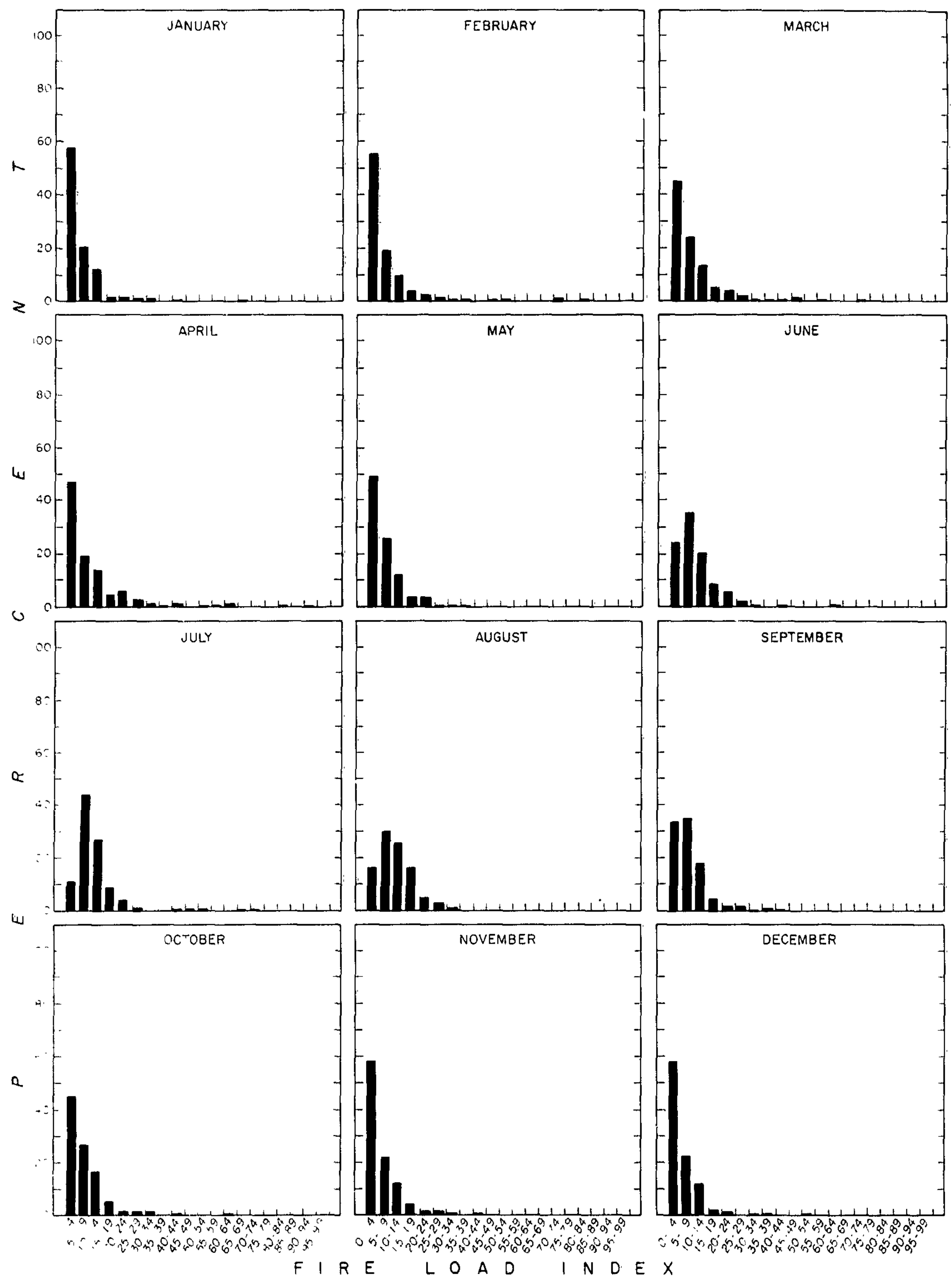
STATION 13962 ABILENE, TEXAS



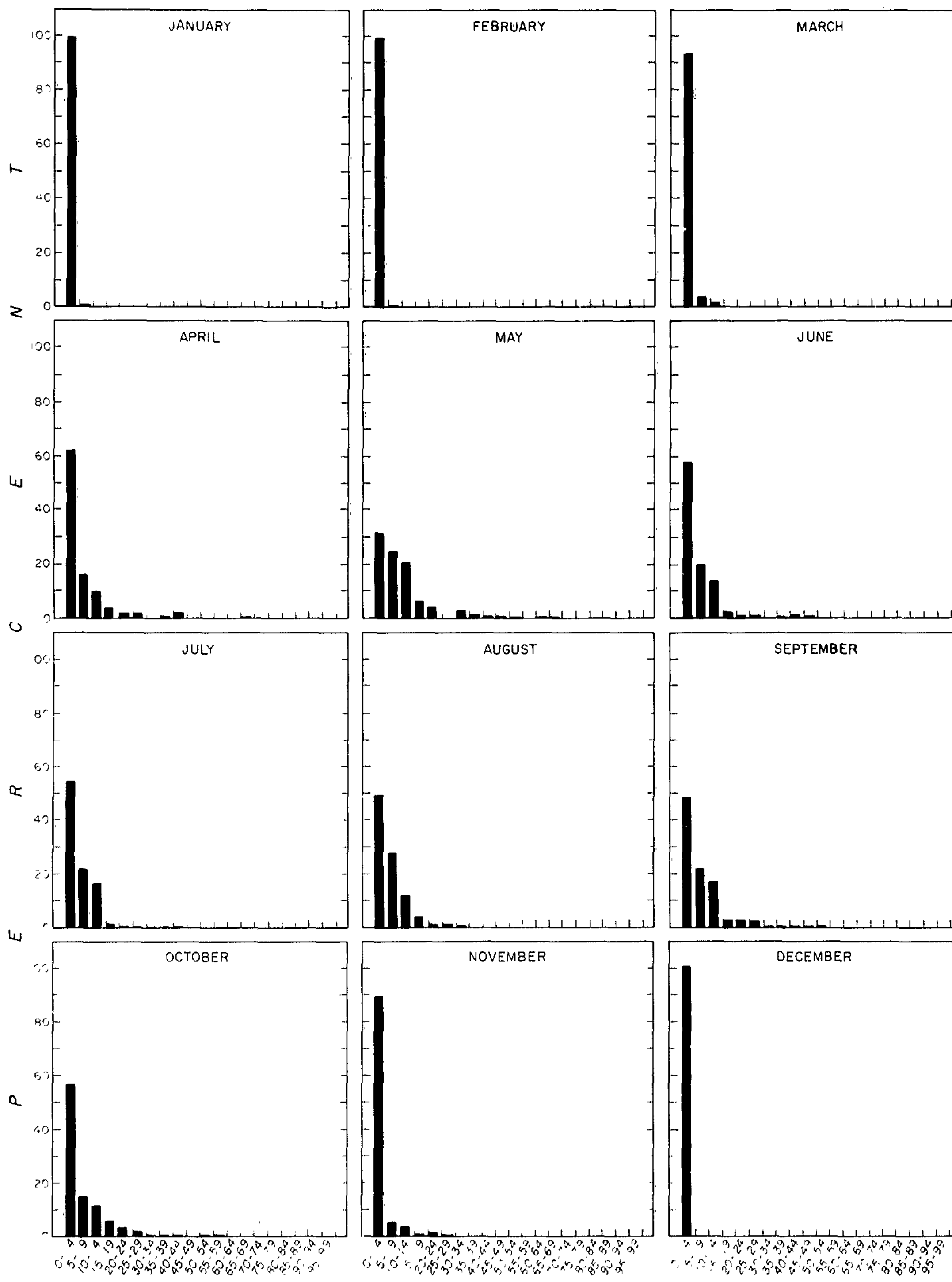
STATION 13959 WACO, TEXAS



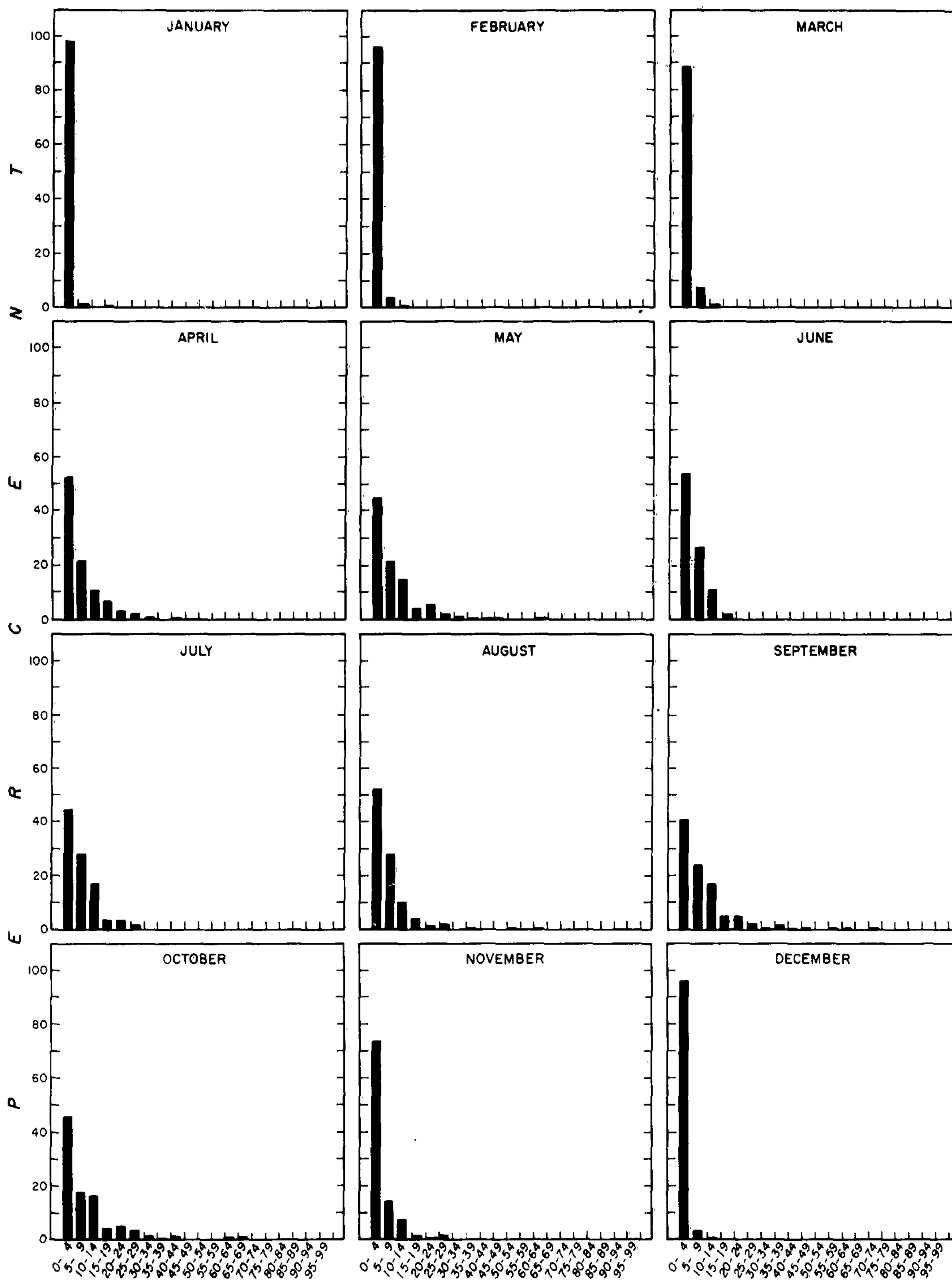
STATION 12921 SAN ANTONIO, TEXAS



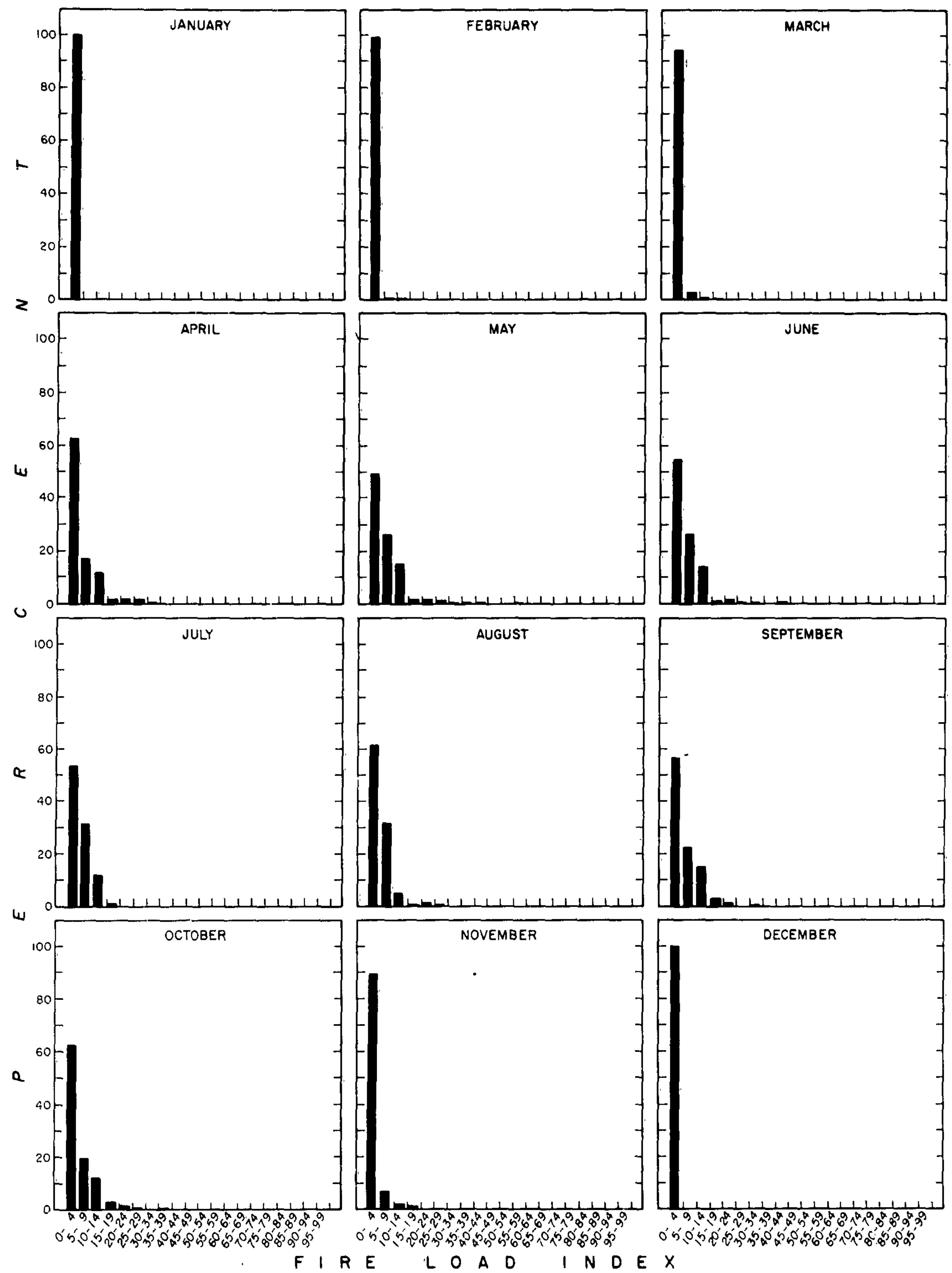
STATION 14914 FARGO, NORTH DAKOTA



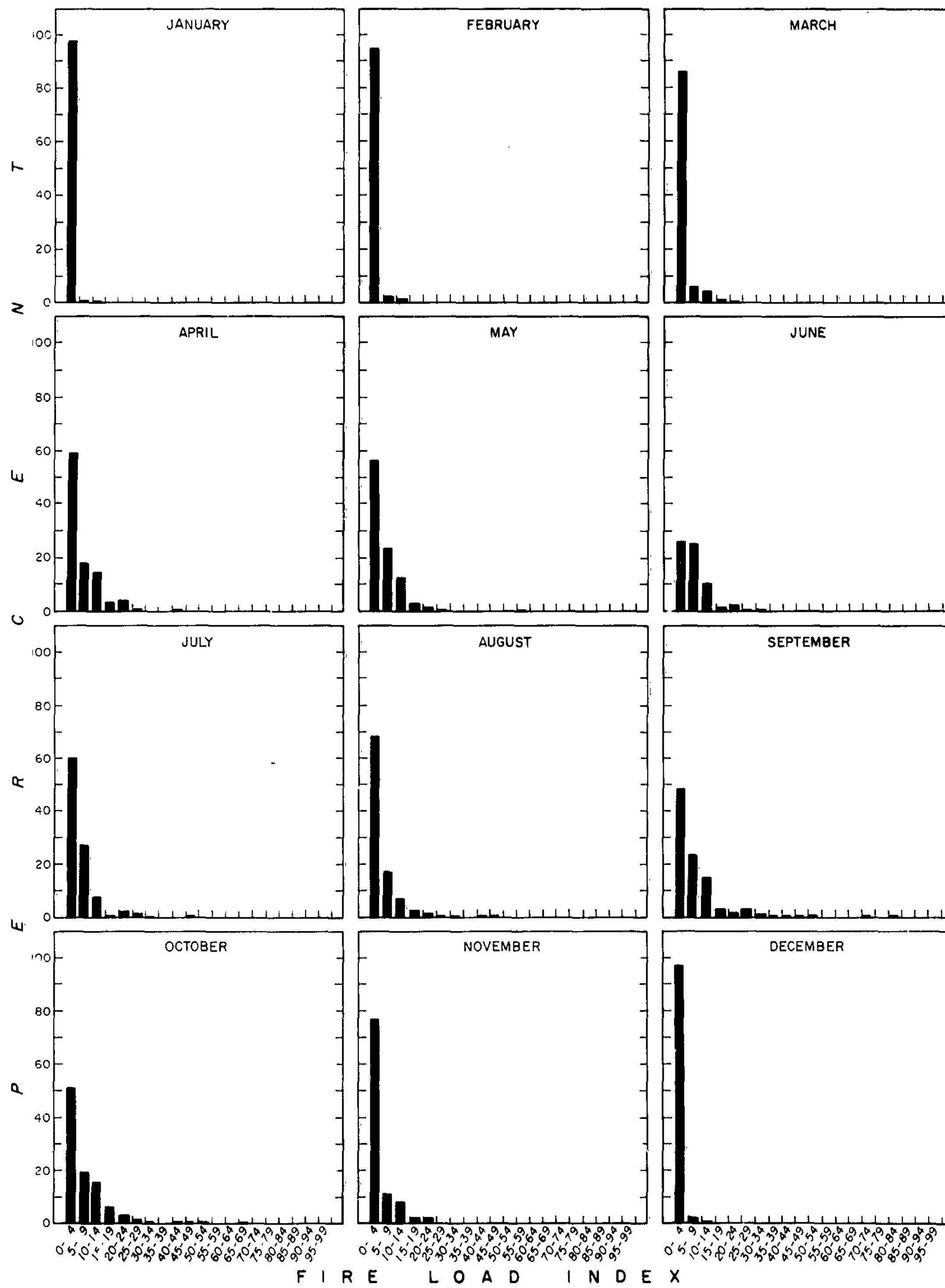
STATION 14944 SIOUX FALLS, SOUTH DAKOTA



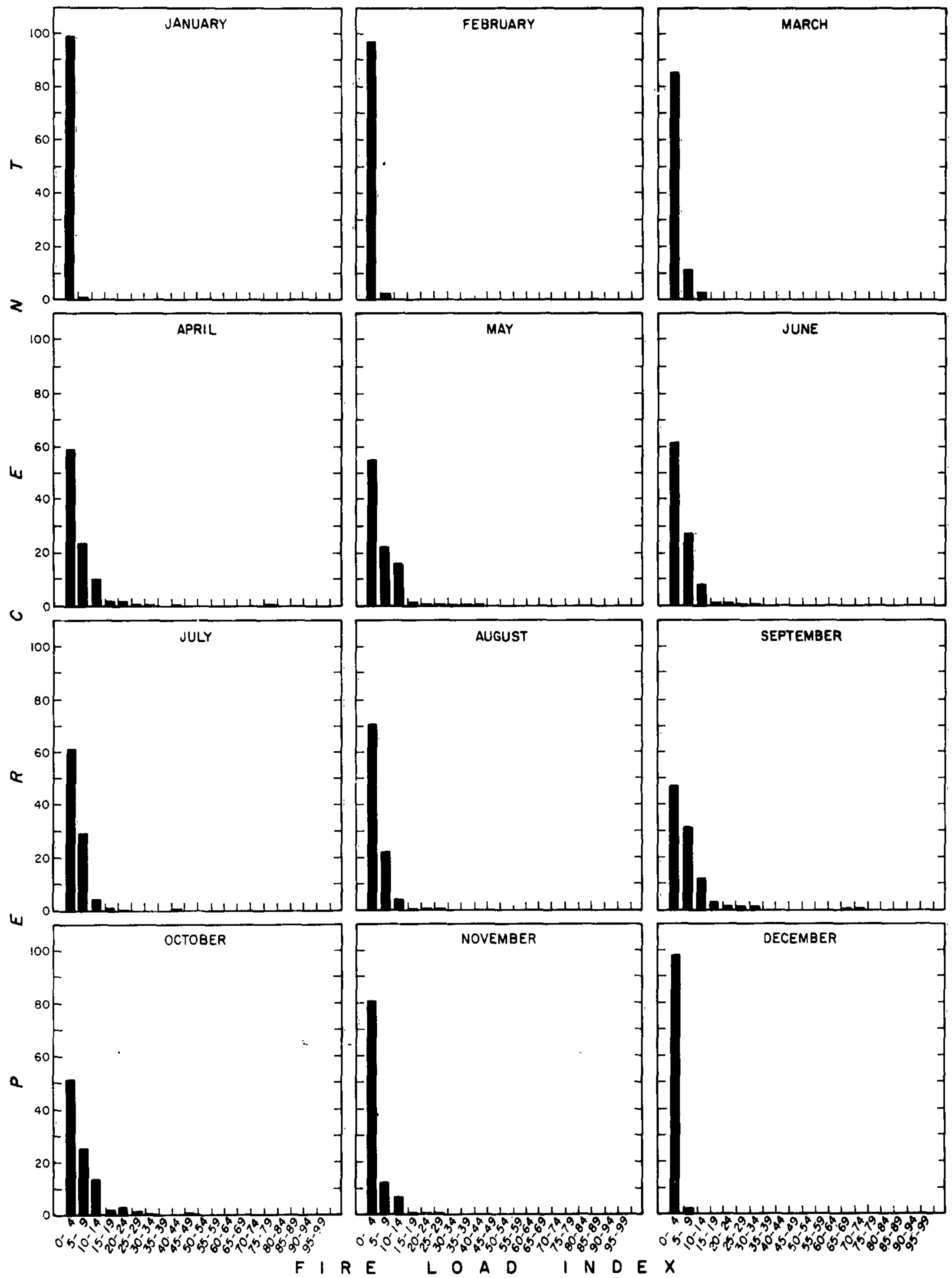
STATION 14922 MINNEAPOLIS, MINNESOTA



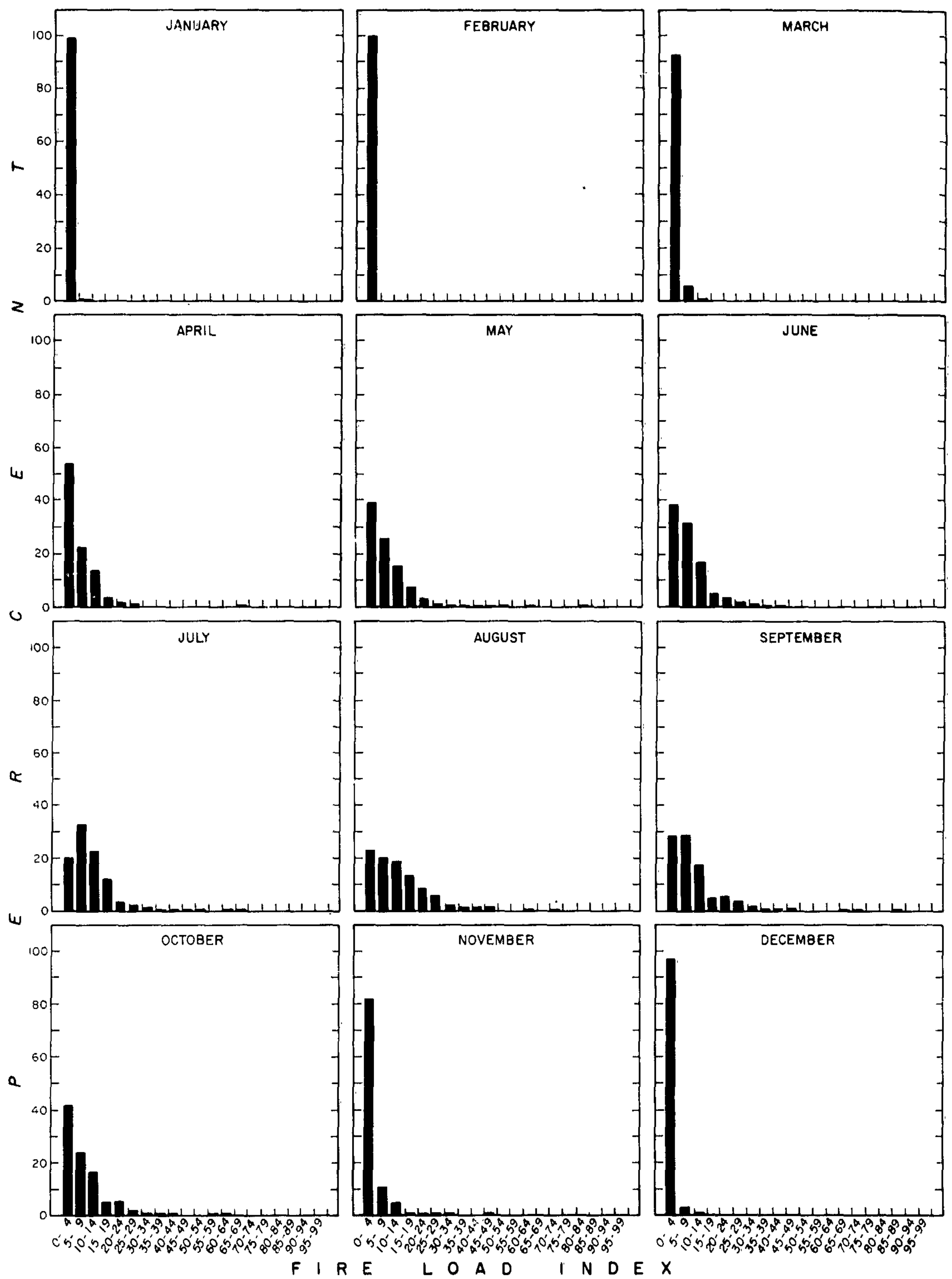
STATION 14933 DES MOINES, IOWA



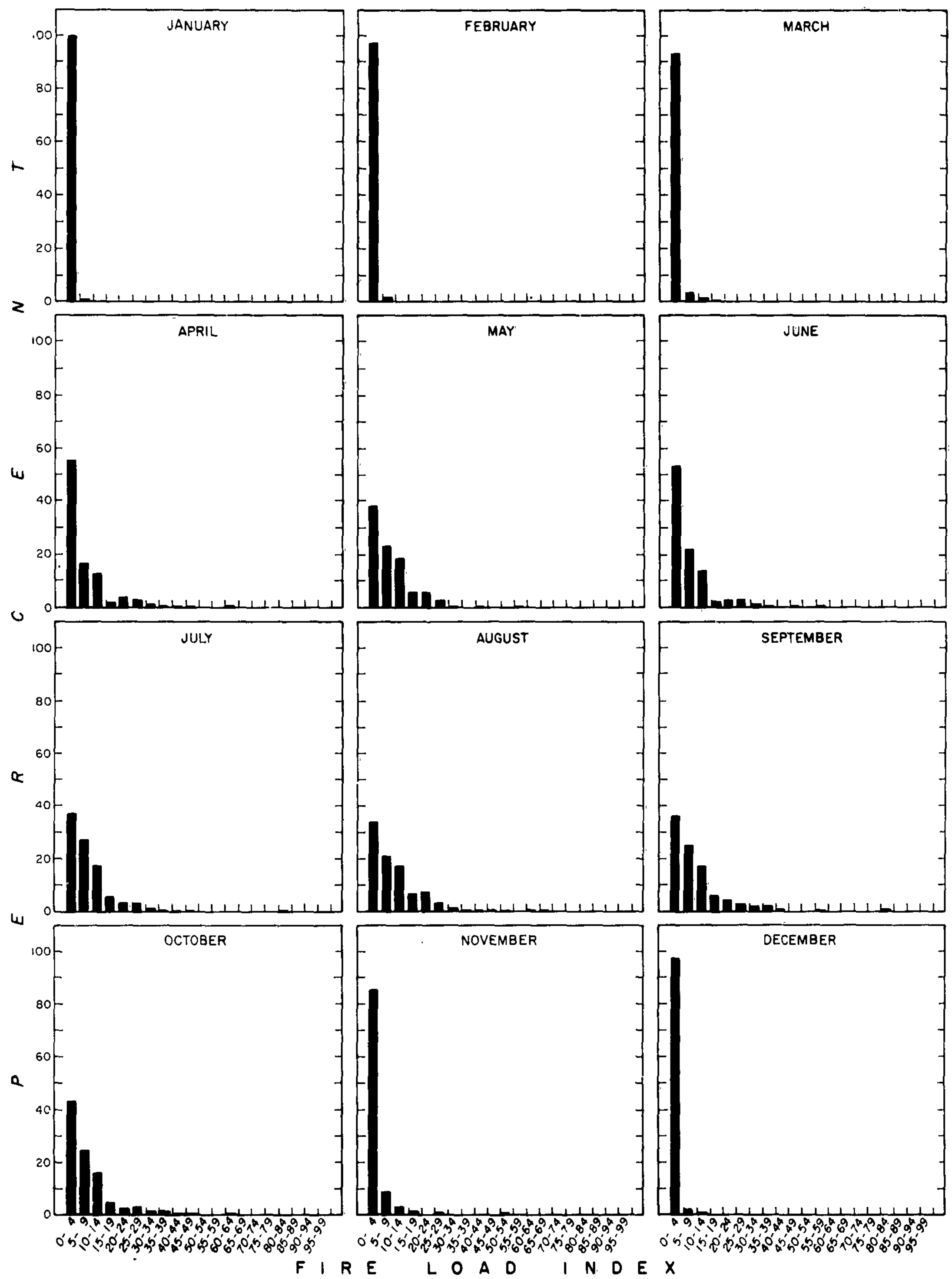
STATION 14923 MOLINE, ILLINOIS



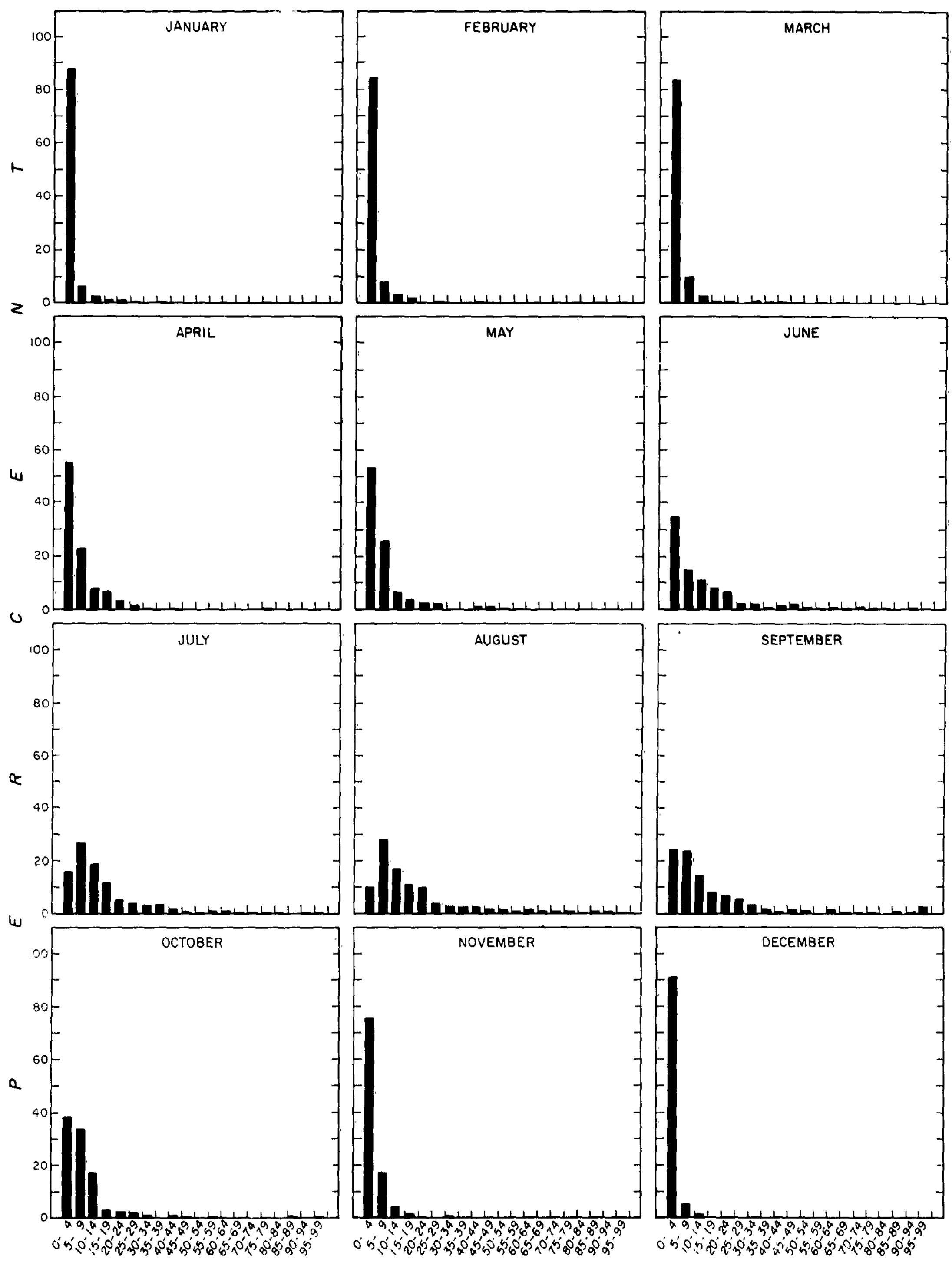
STATION 94008 GLASGOW, MONTANA



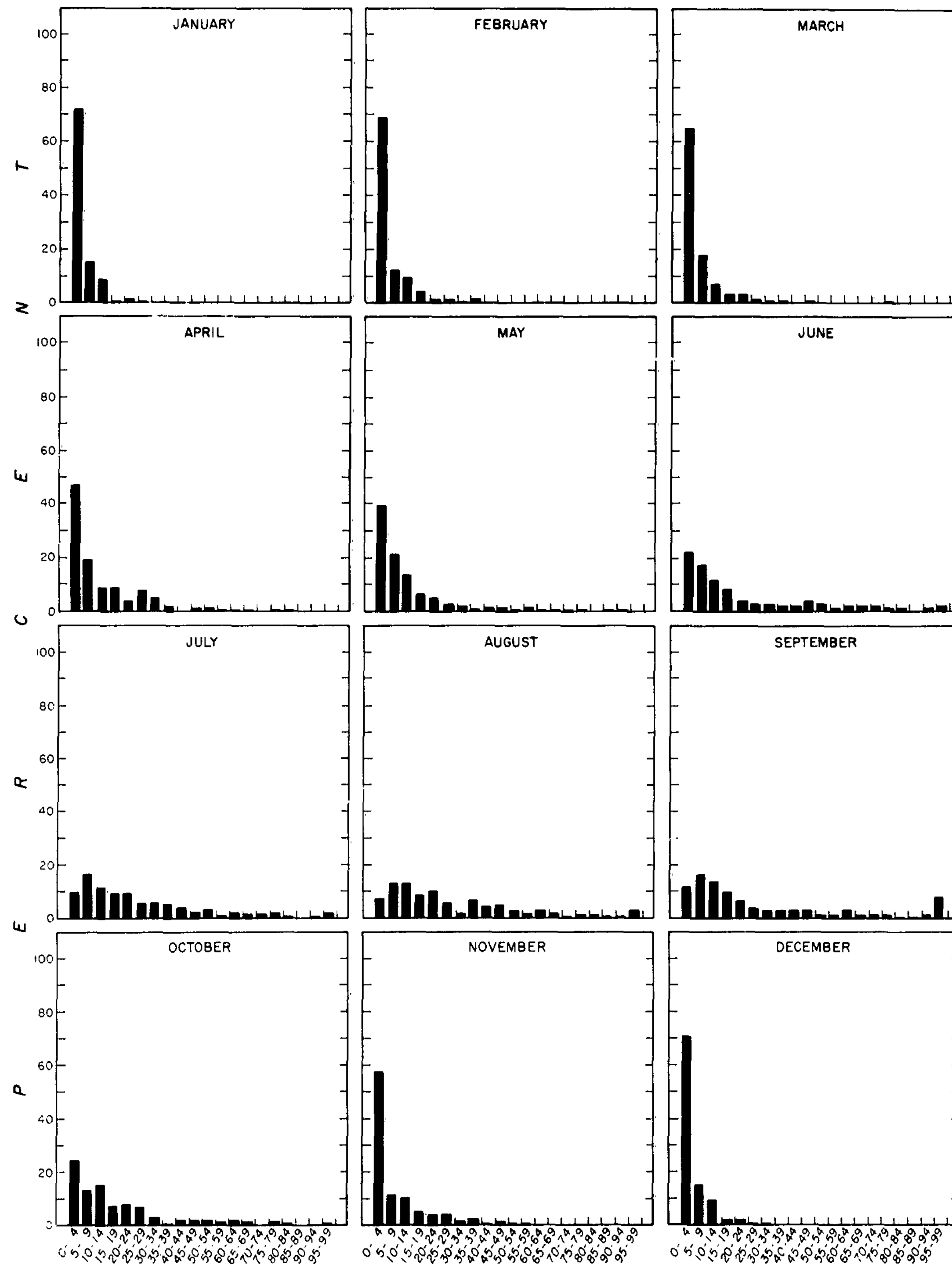
STATION 24011 BISMARCK, NORTH DAKOTA



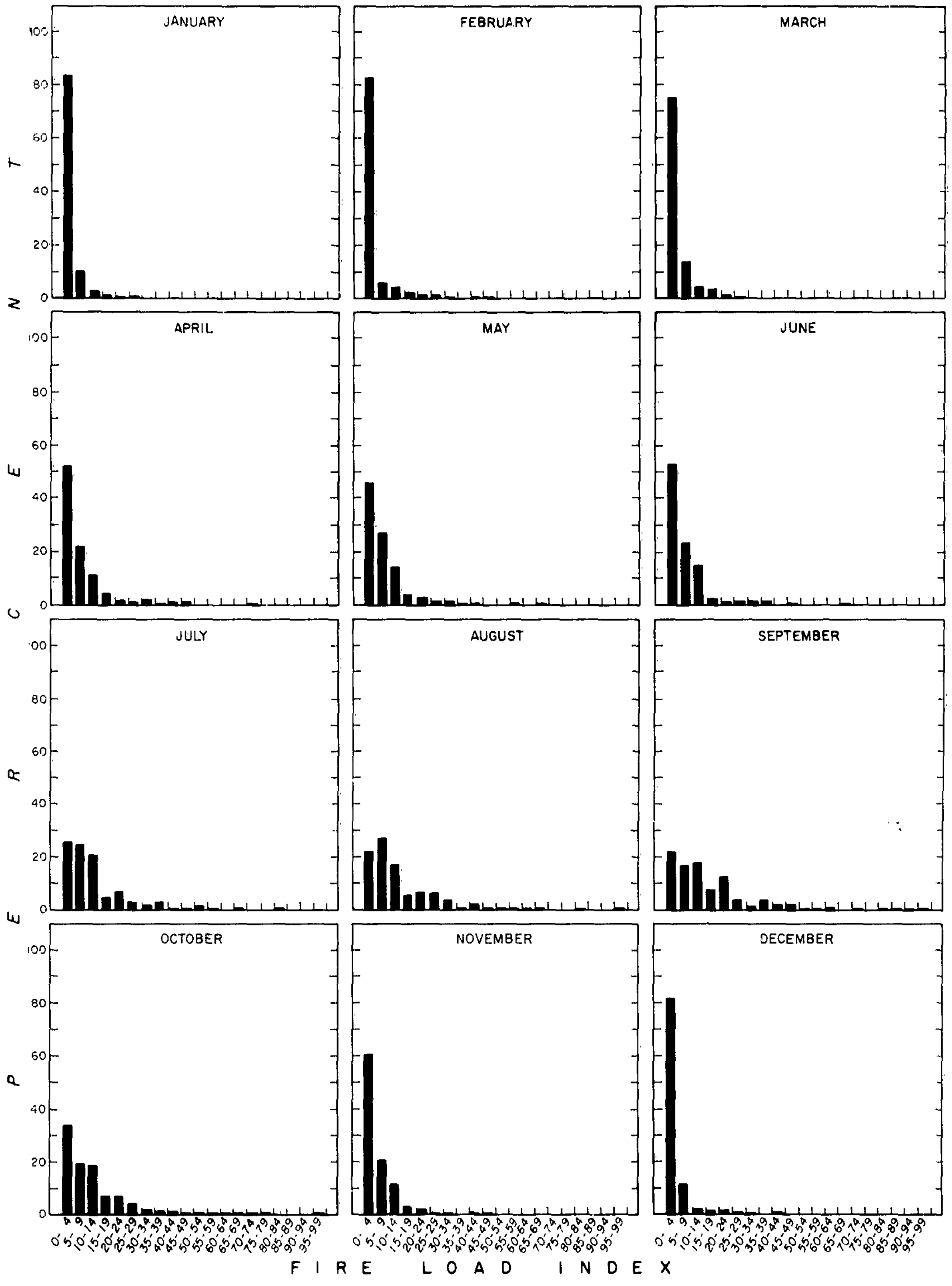
STATION 24021 LANDER, WYOMING



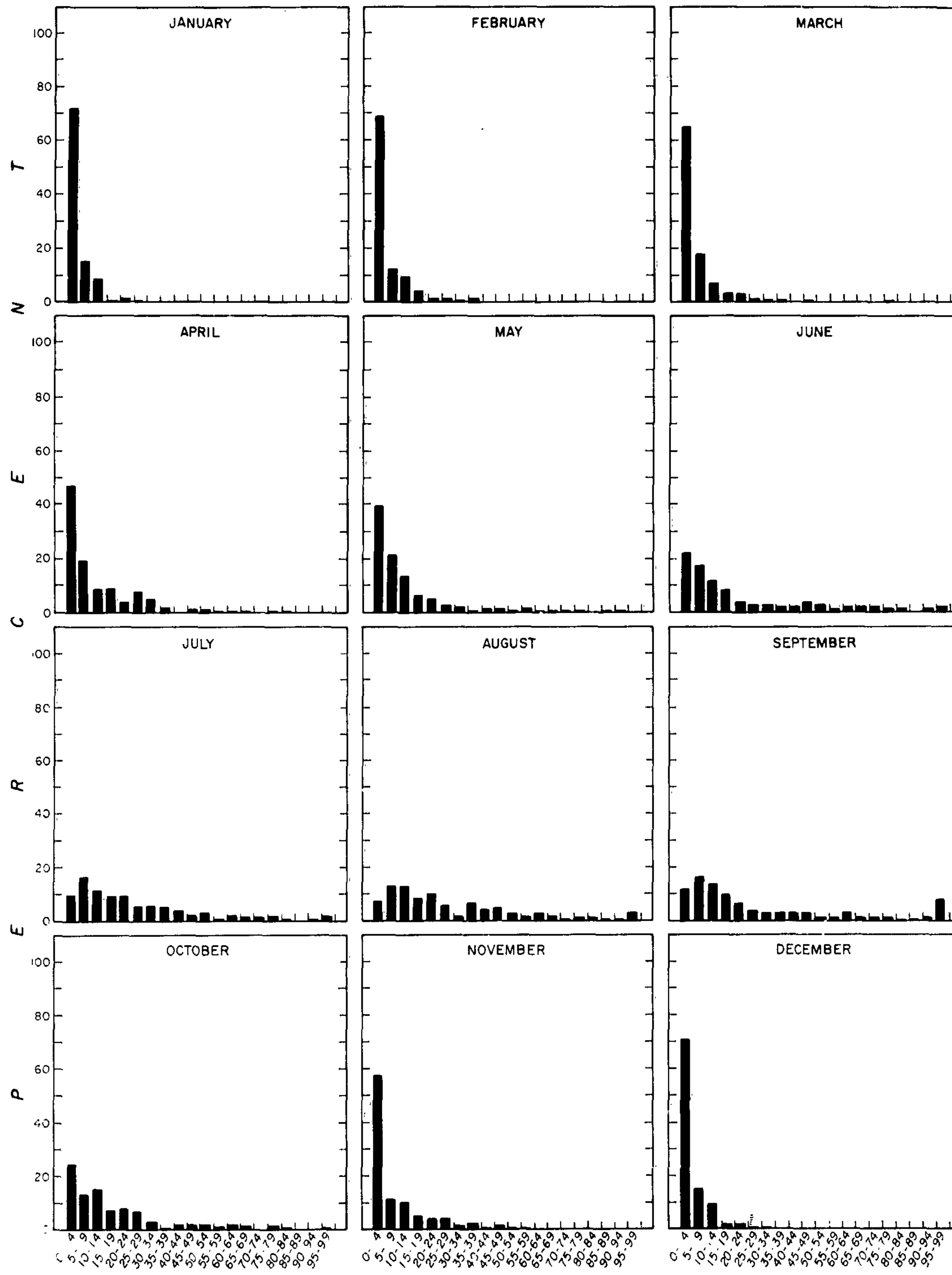
STATION 24089 CASPER, WYOMING



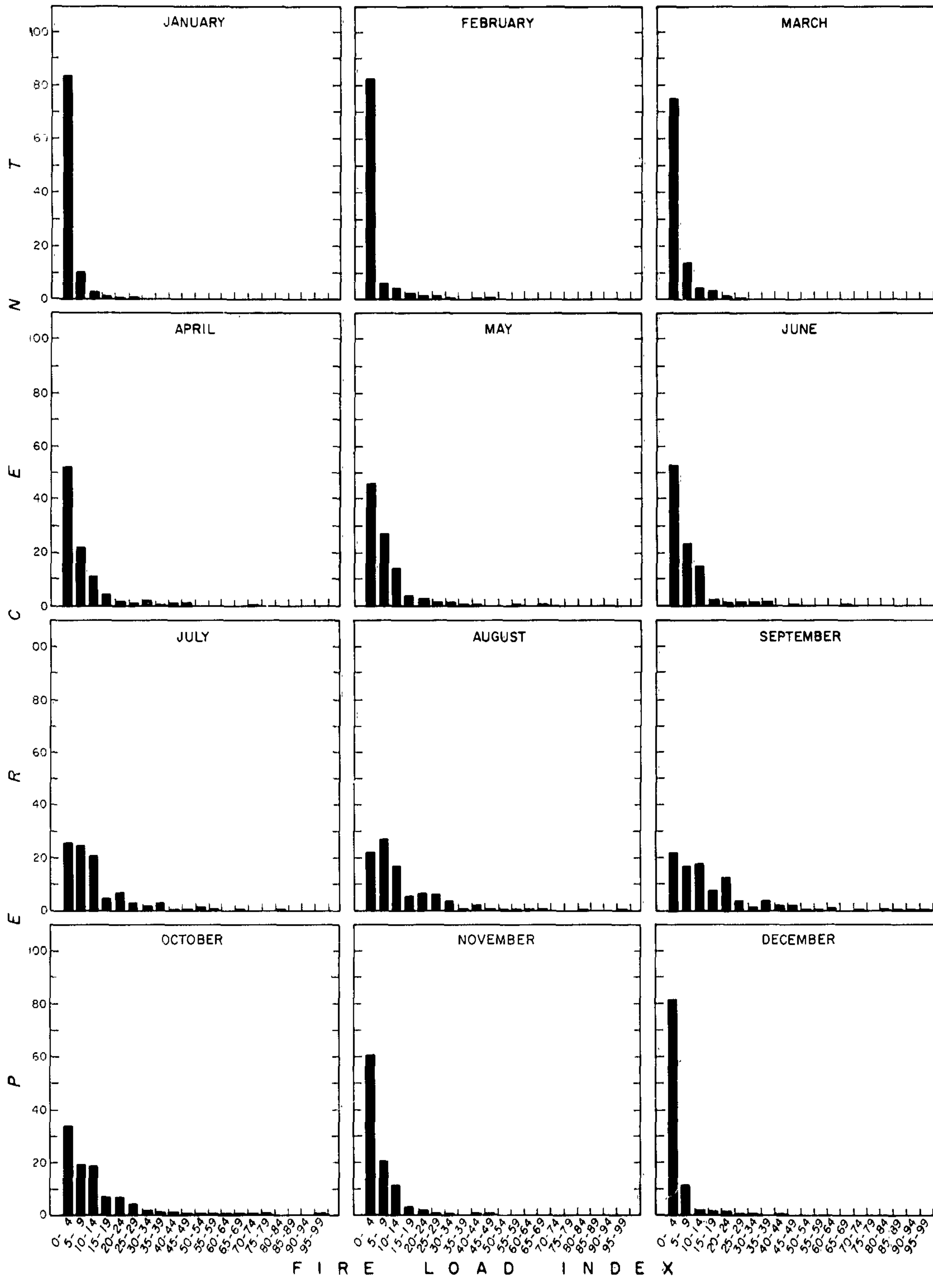
STATION 24090 RAPID CITY, SOUTH DAKOTA



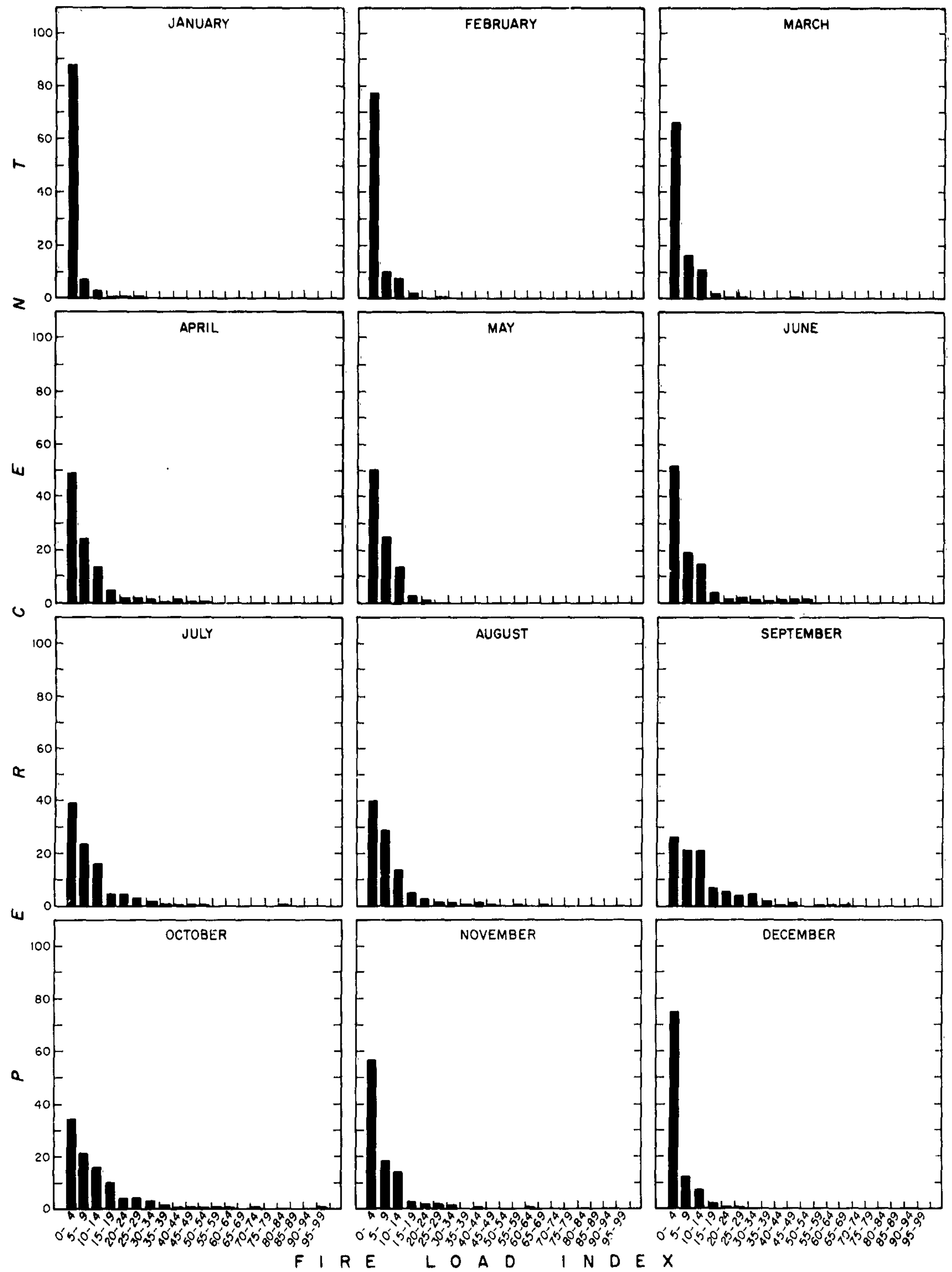
STATION 24089 CASPER, WYOMING



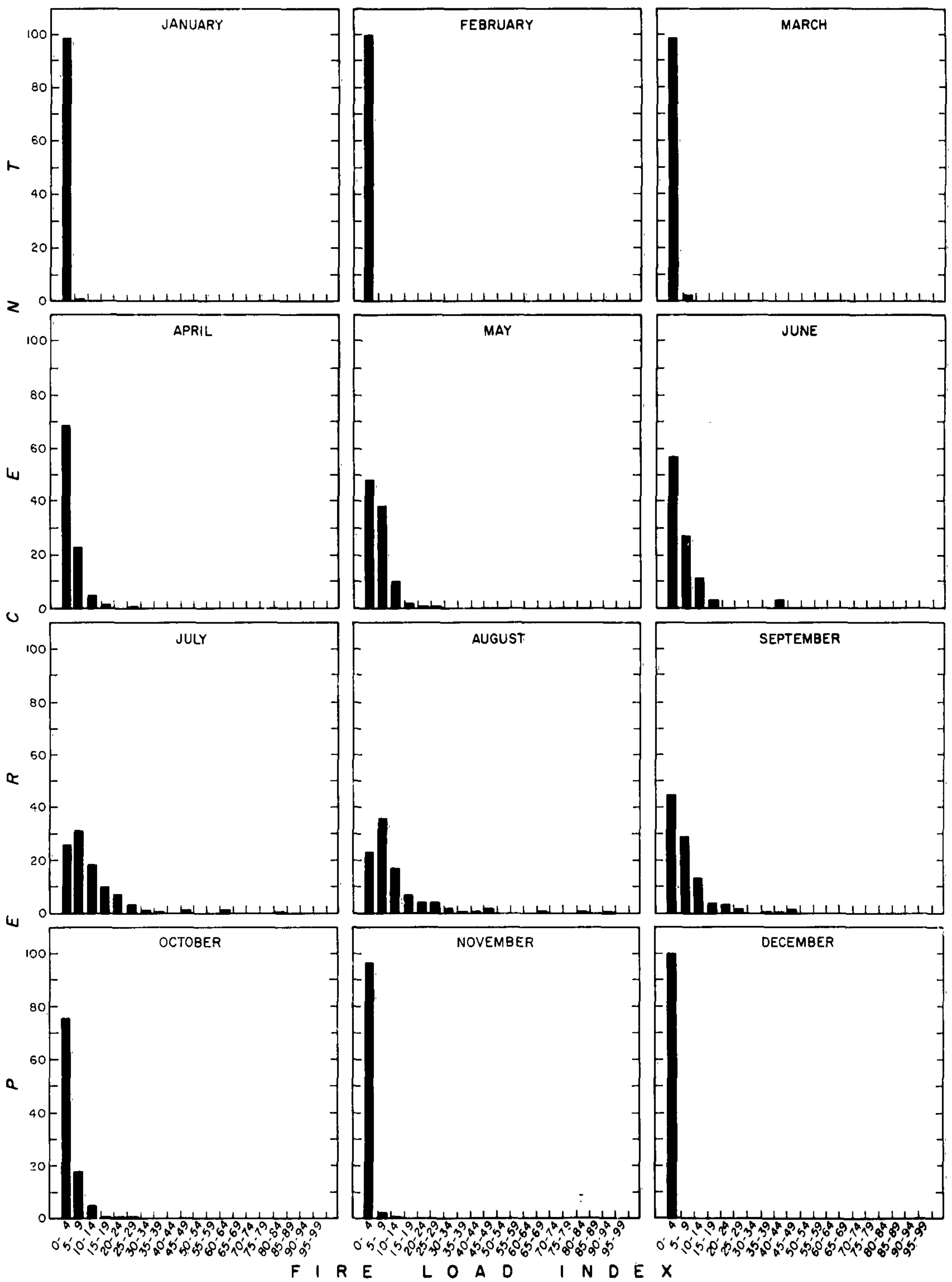
STATION 24090 RAPID CITY, SOUTH DAKOTA



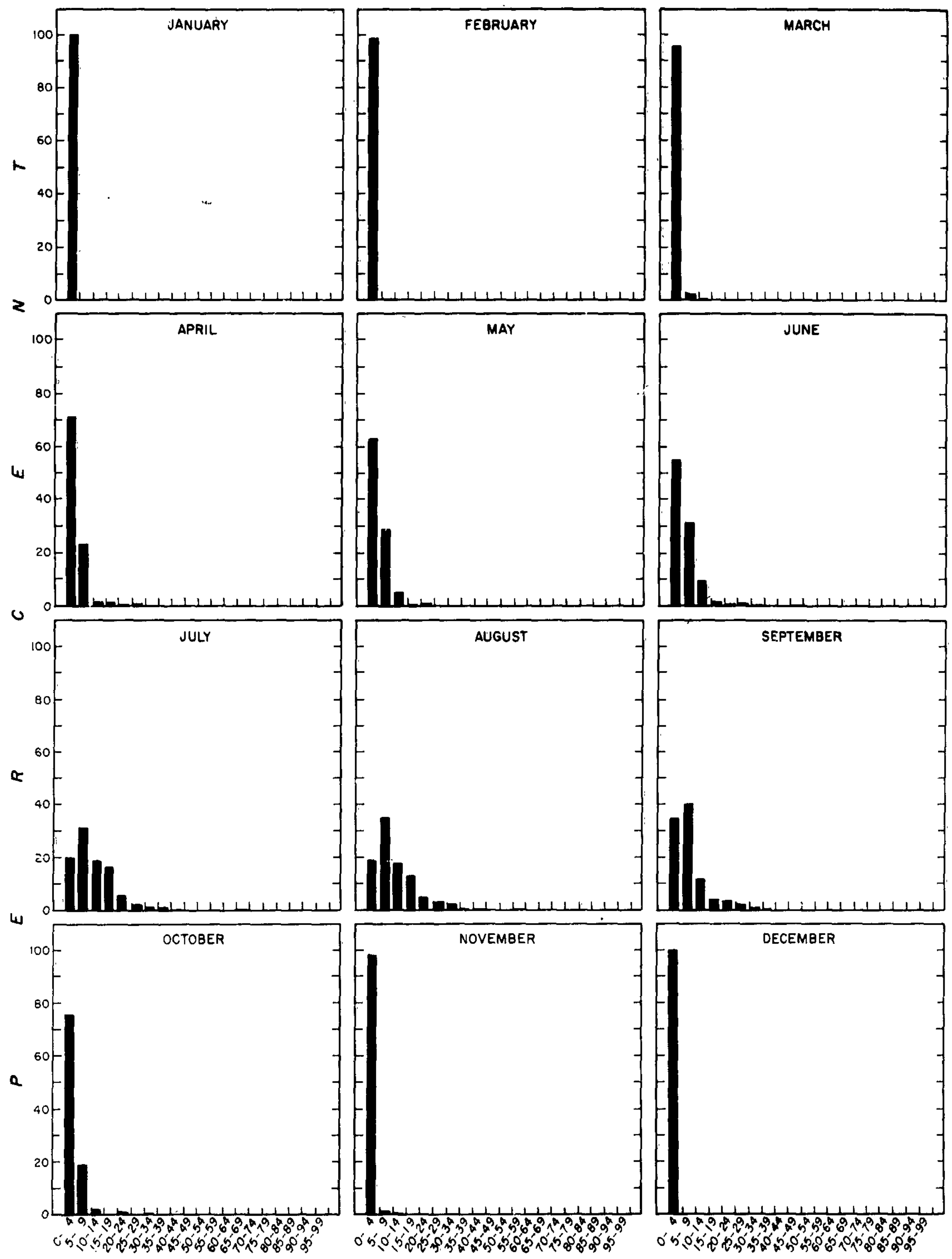
STATION 24023 NORTH PLATTE, NEBRASKA



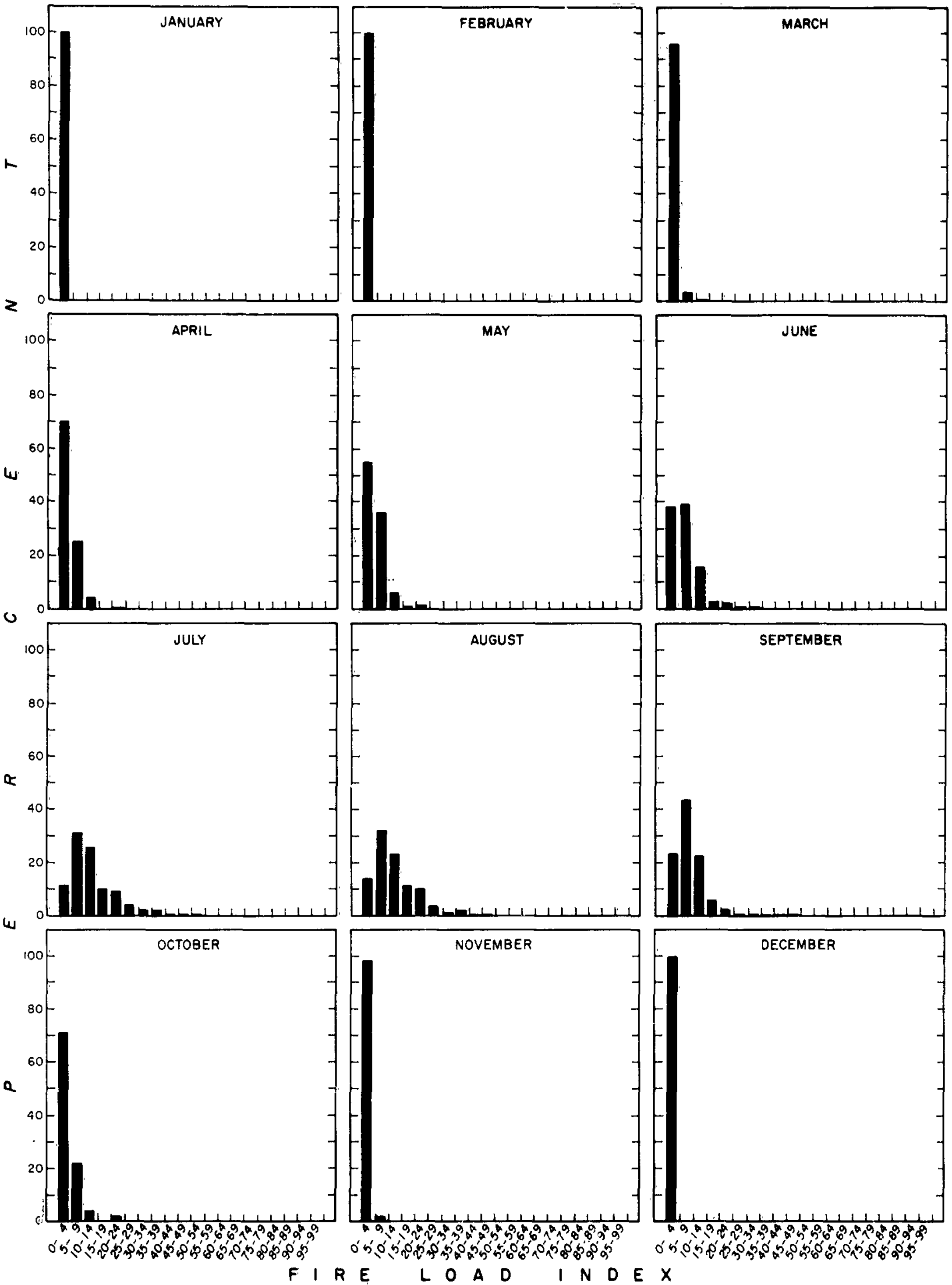
STATION 24146 KALISPELL, MONTANA



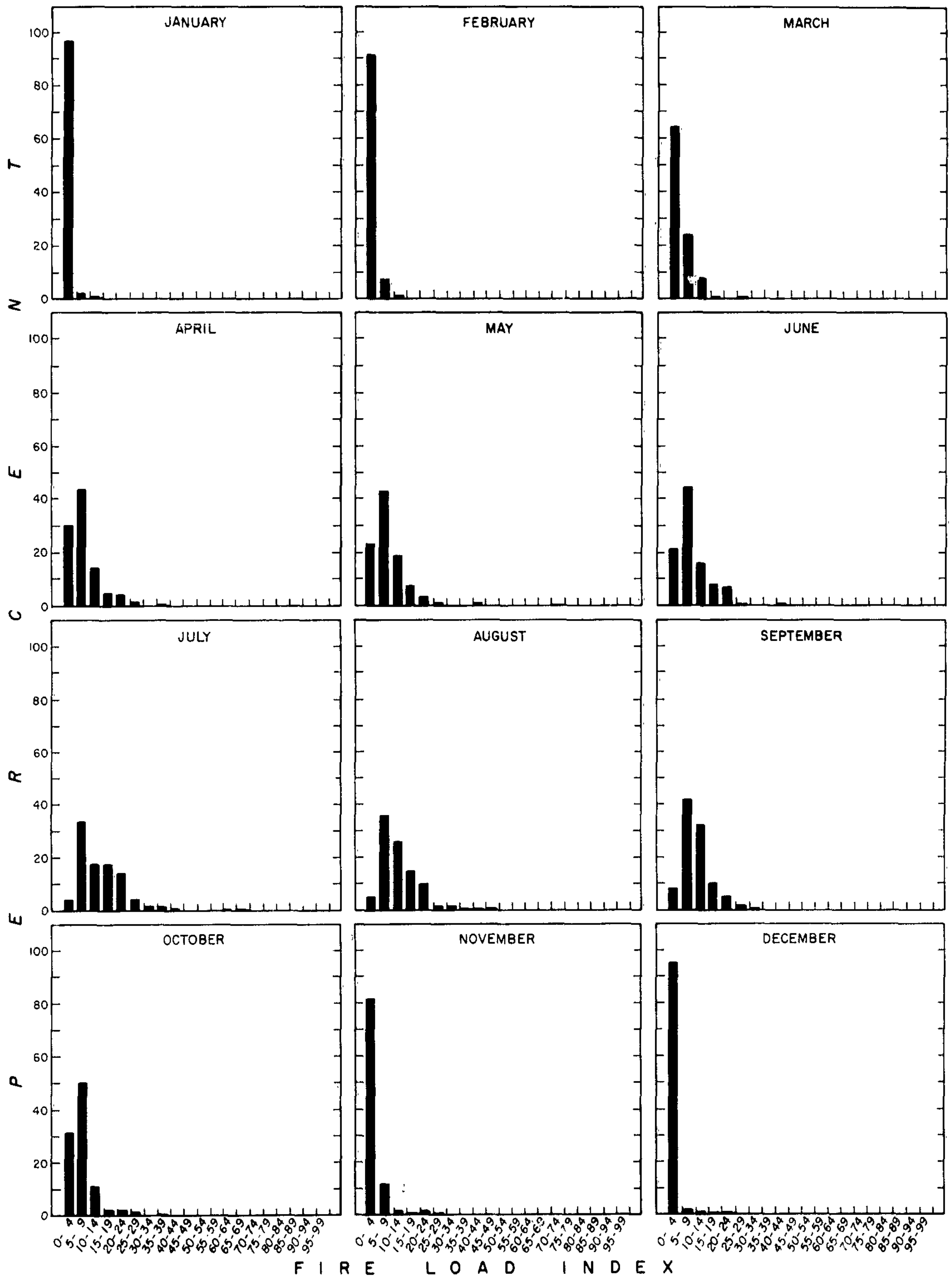
STATION 24153 MISSOULA, MONTANA



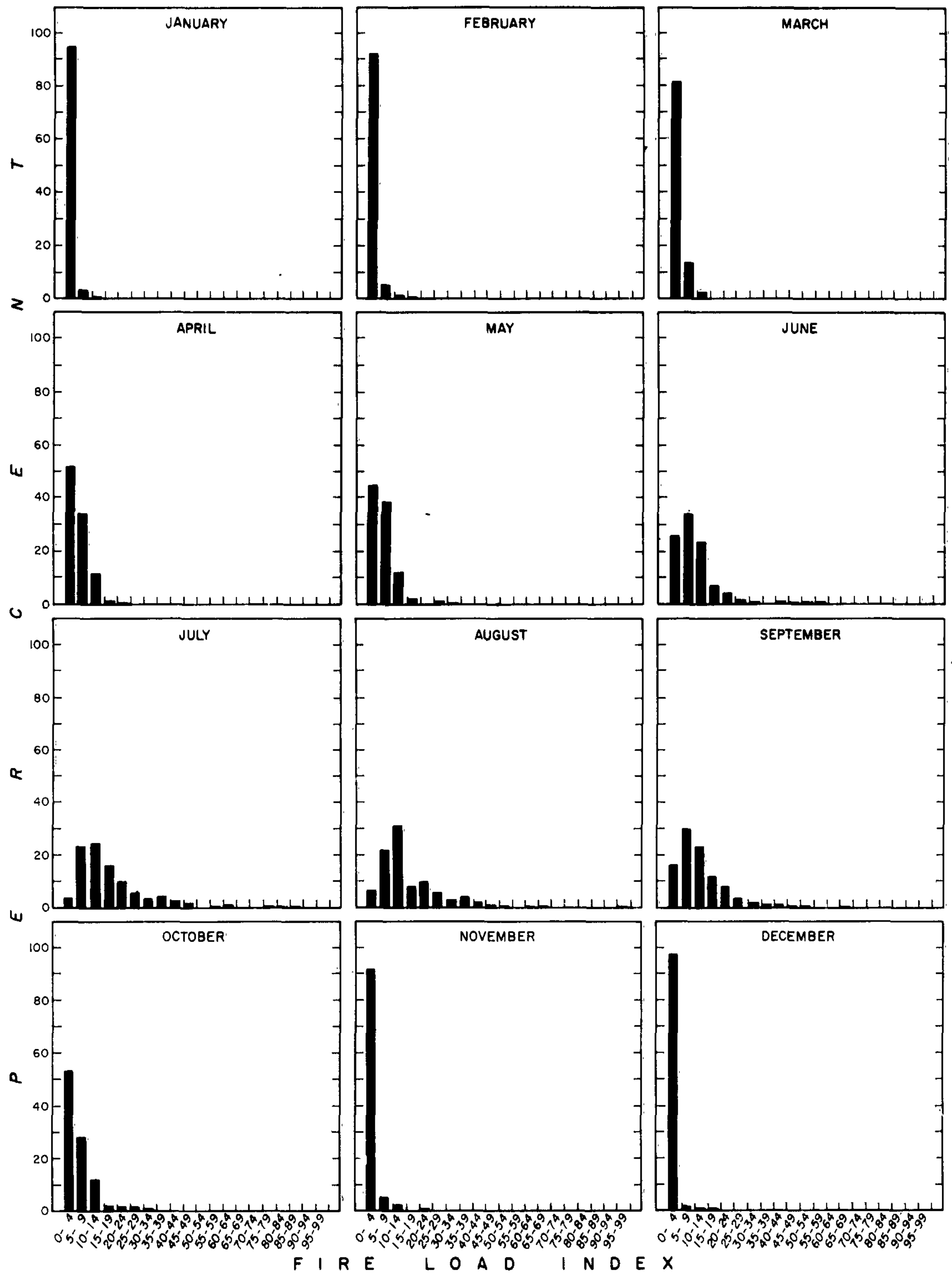
STATION 24157 SPOKANE, WASHINGTON



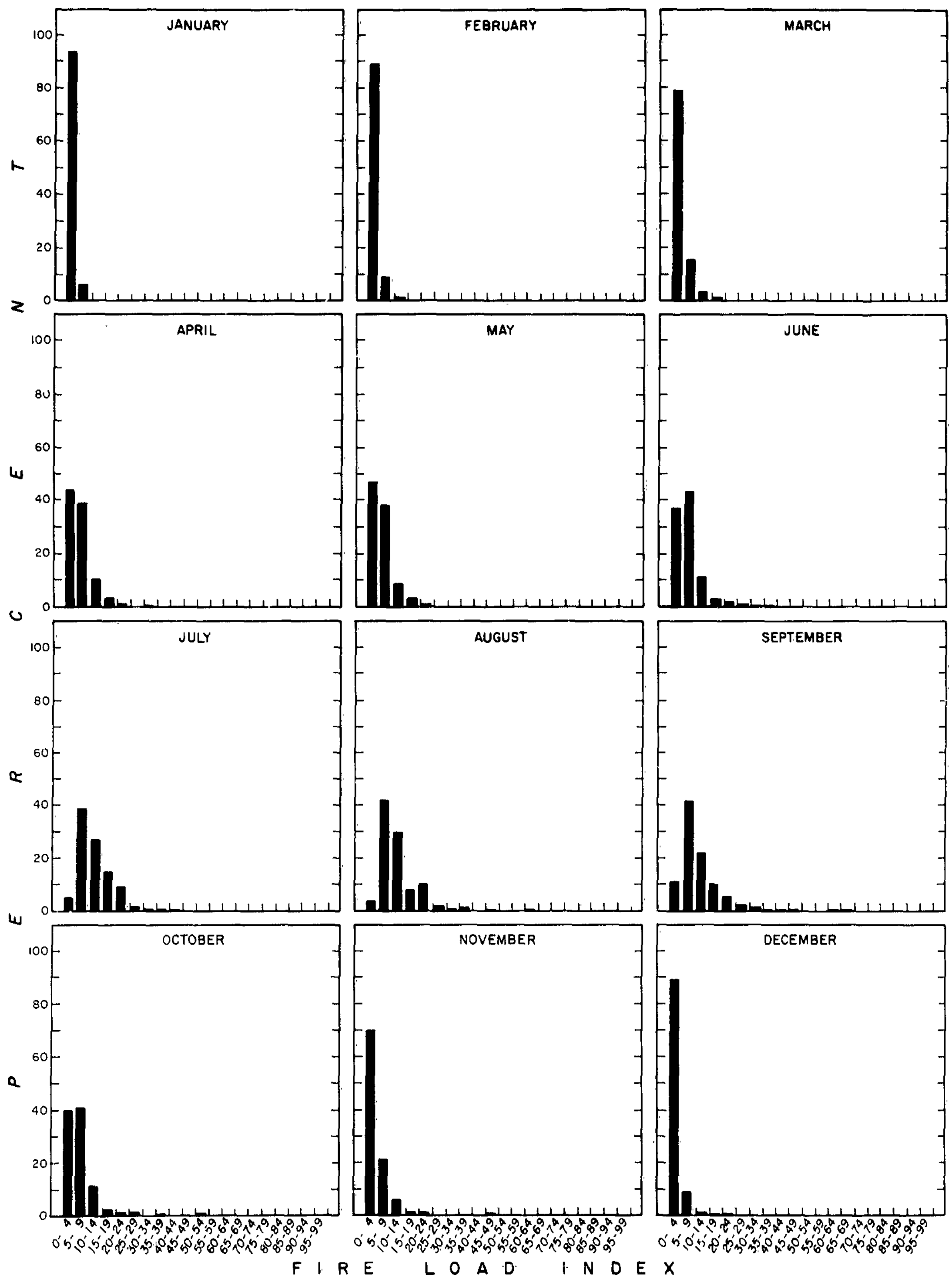
STATION 24243 YAKIMA, WASHINGTON



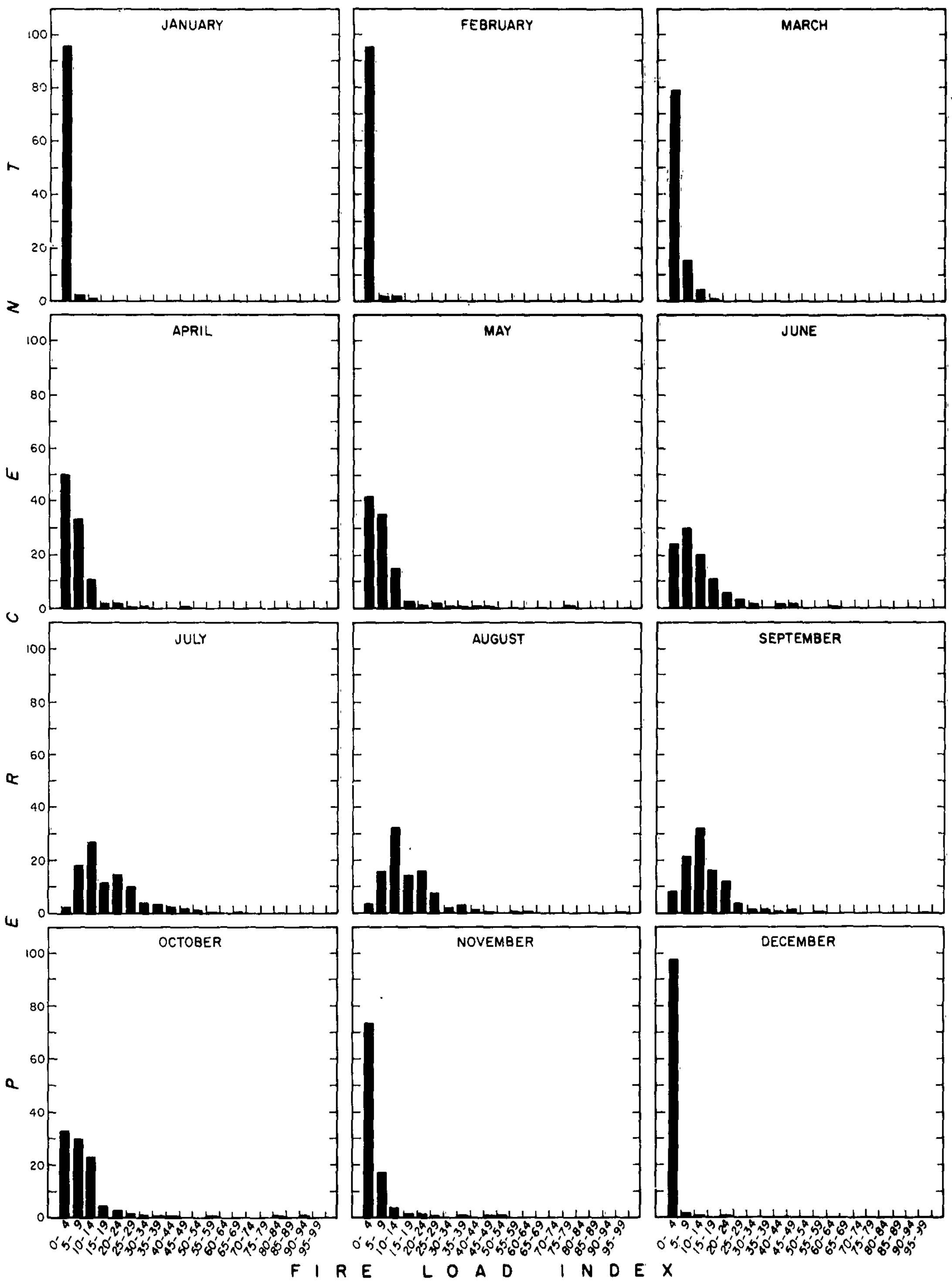
STATION 24155 PENDLETON, OREGON



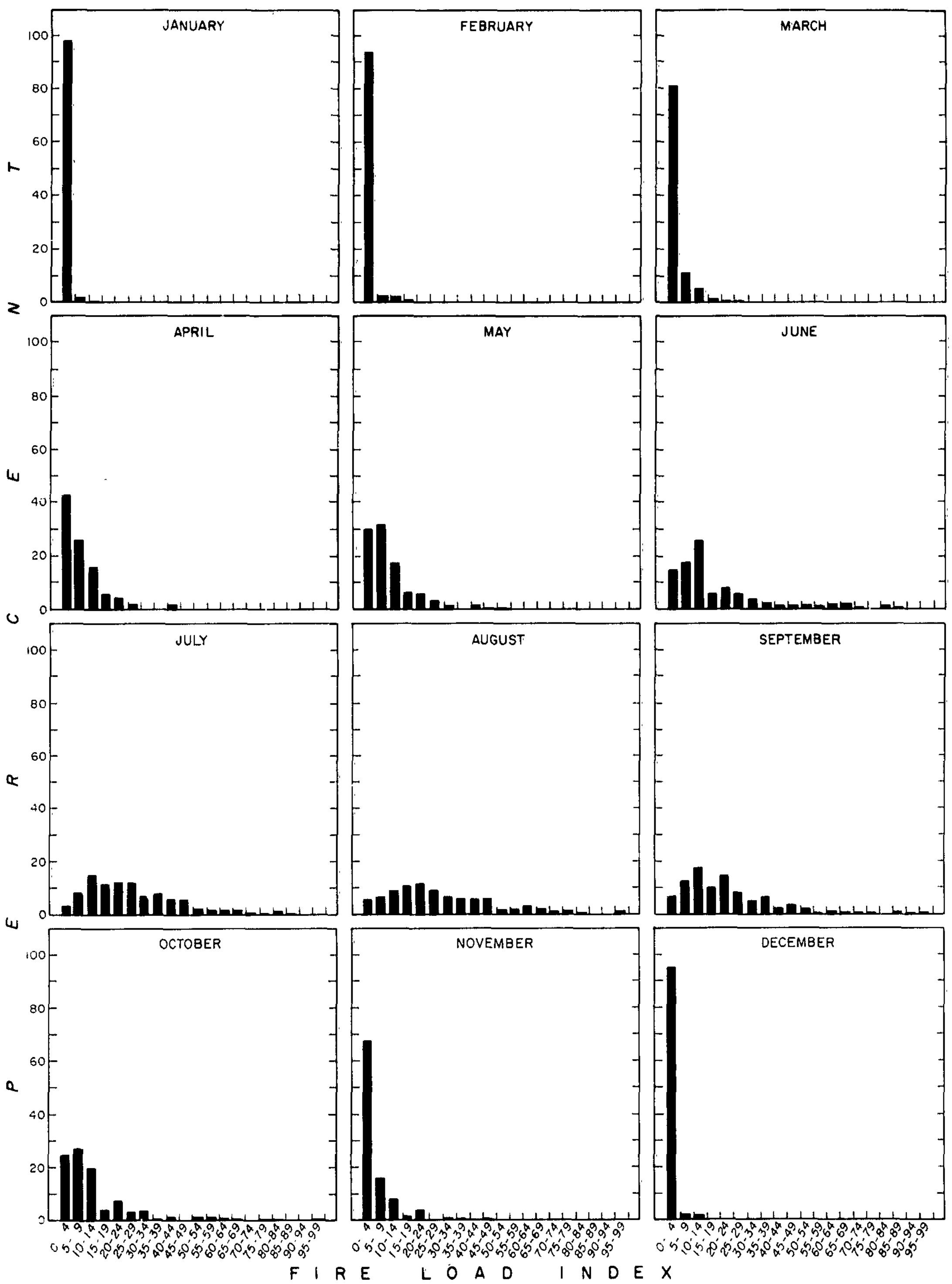
STATION 24230 REDMOND, OREGON



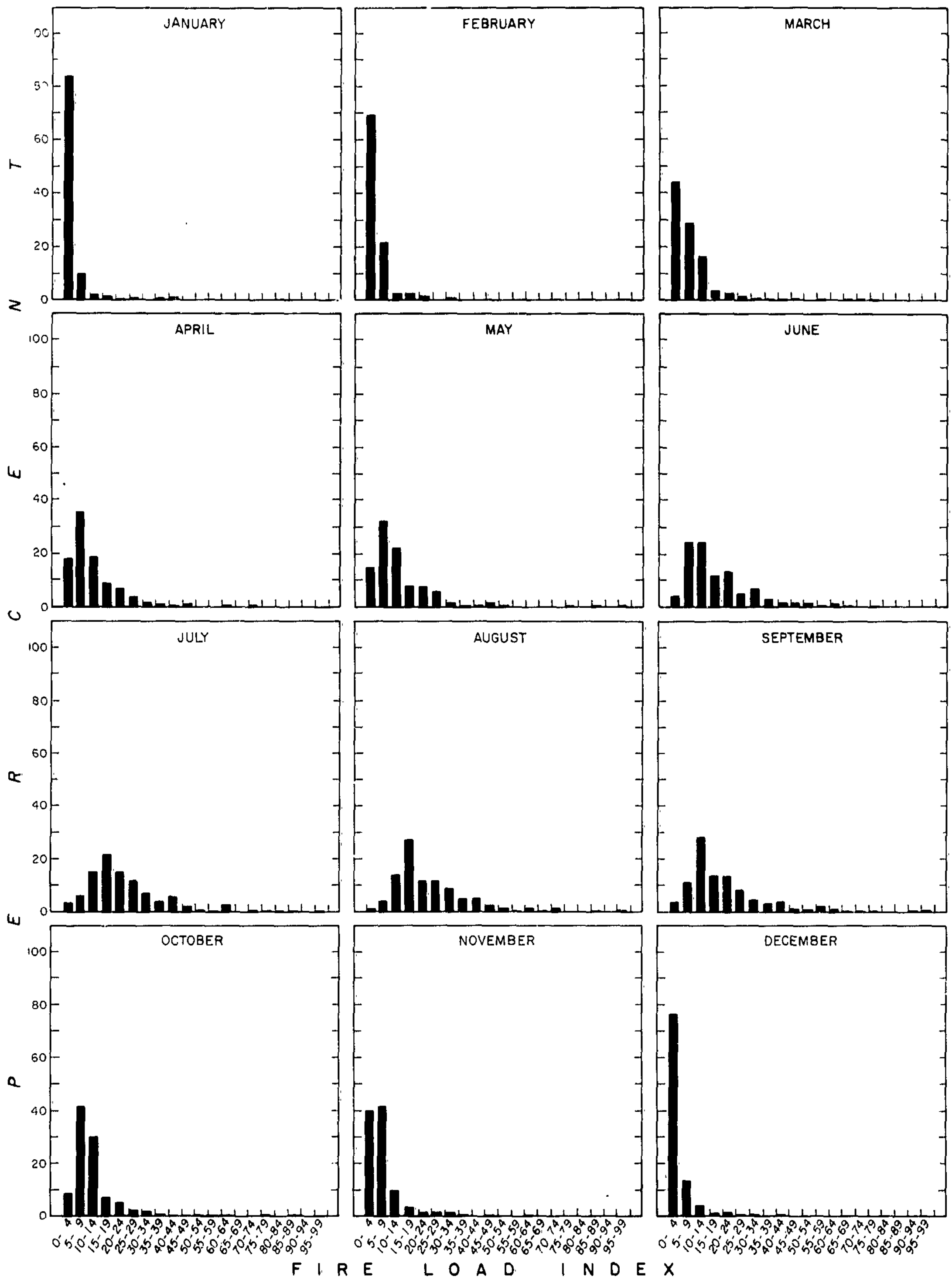
STATION 24131 BOISE, IDAHO



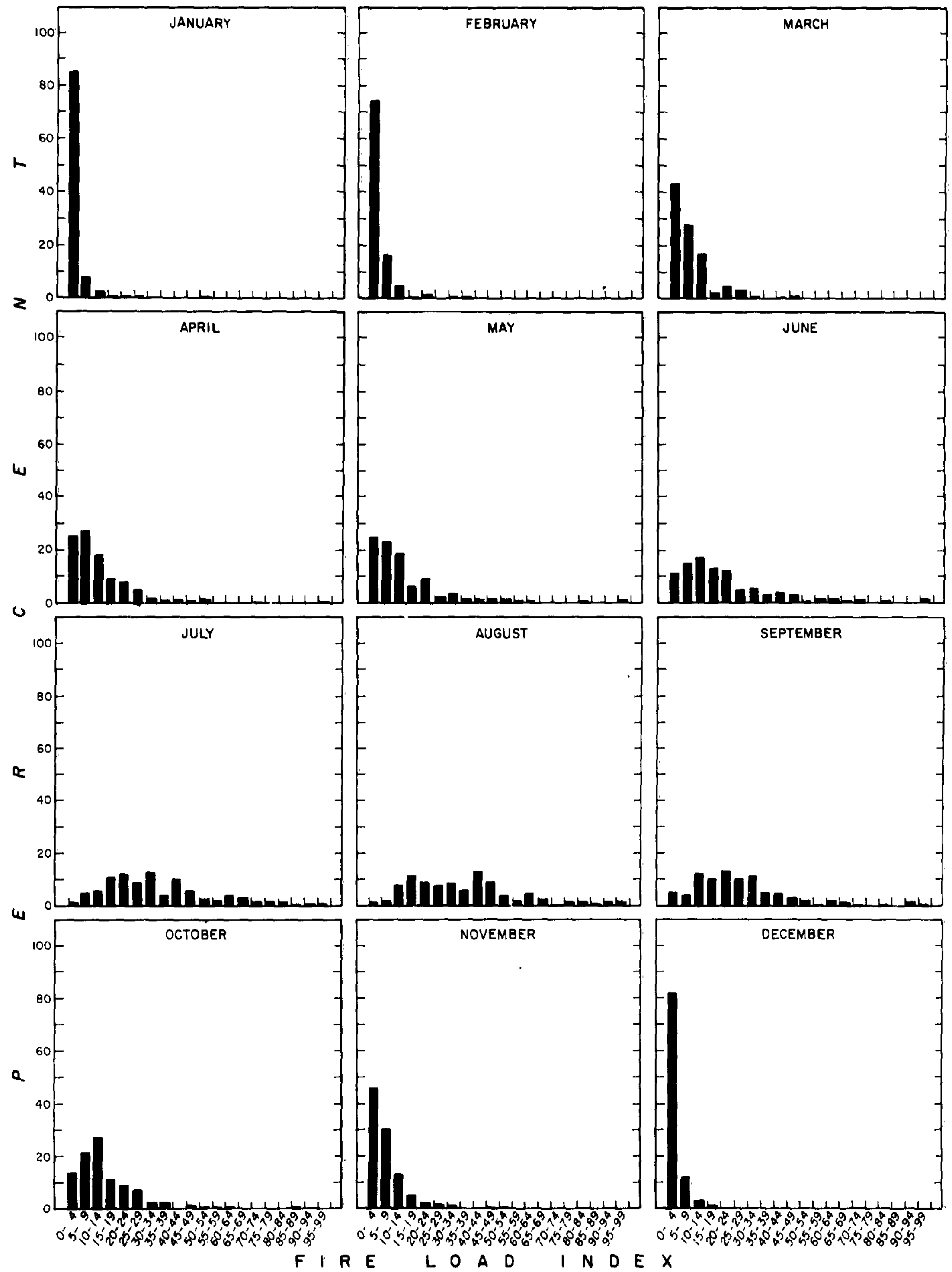
STATION 24156 POCATELLO, IDAHO



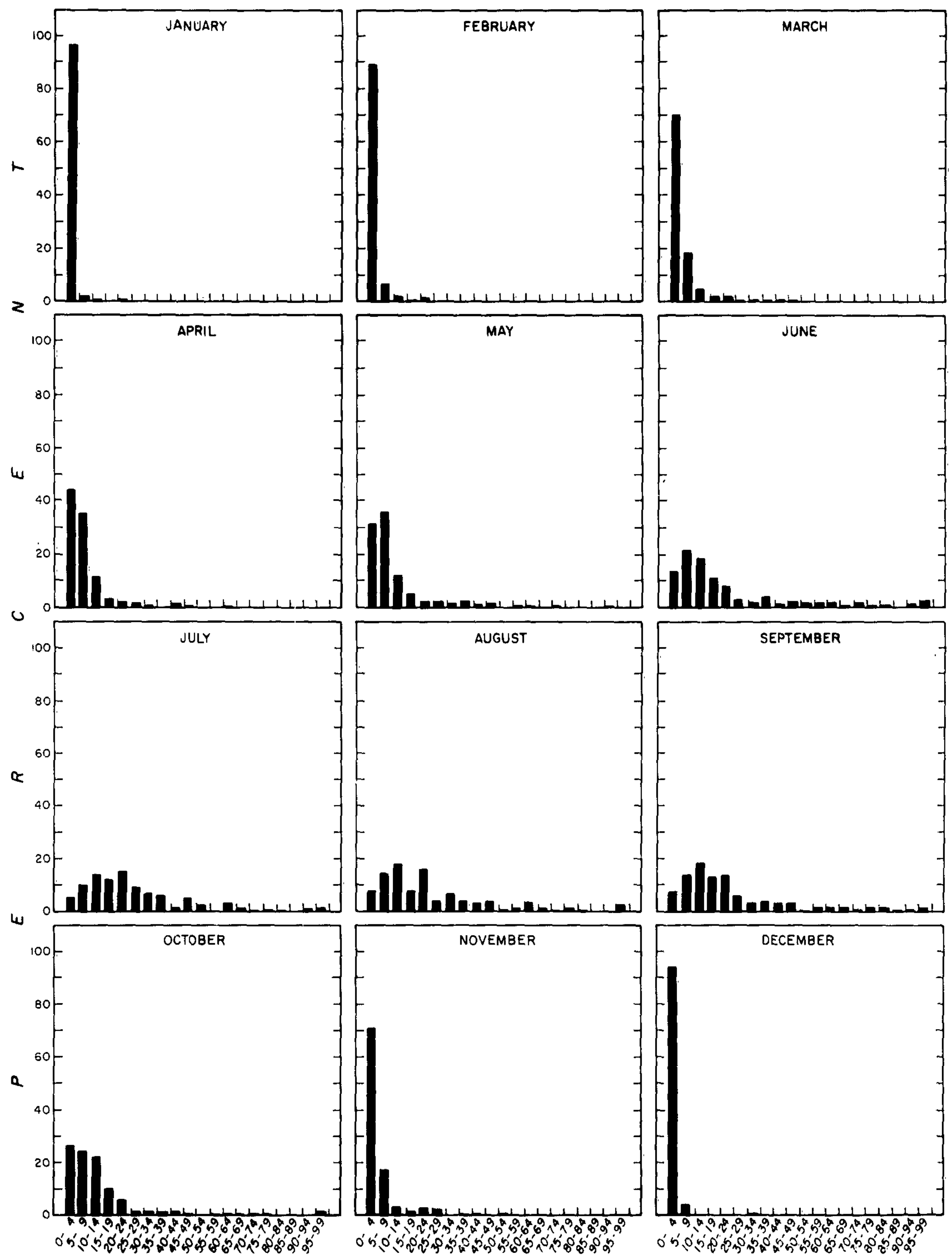
STATION 23185 RENO, NEVADA



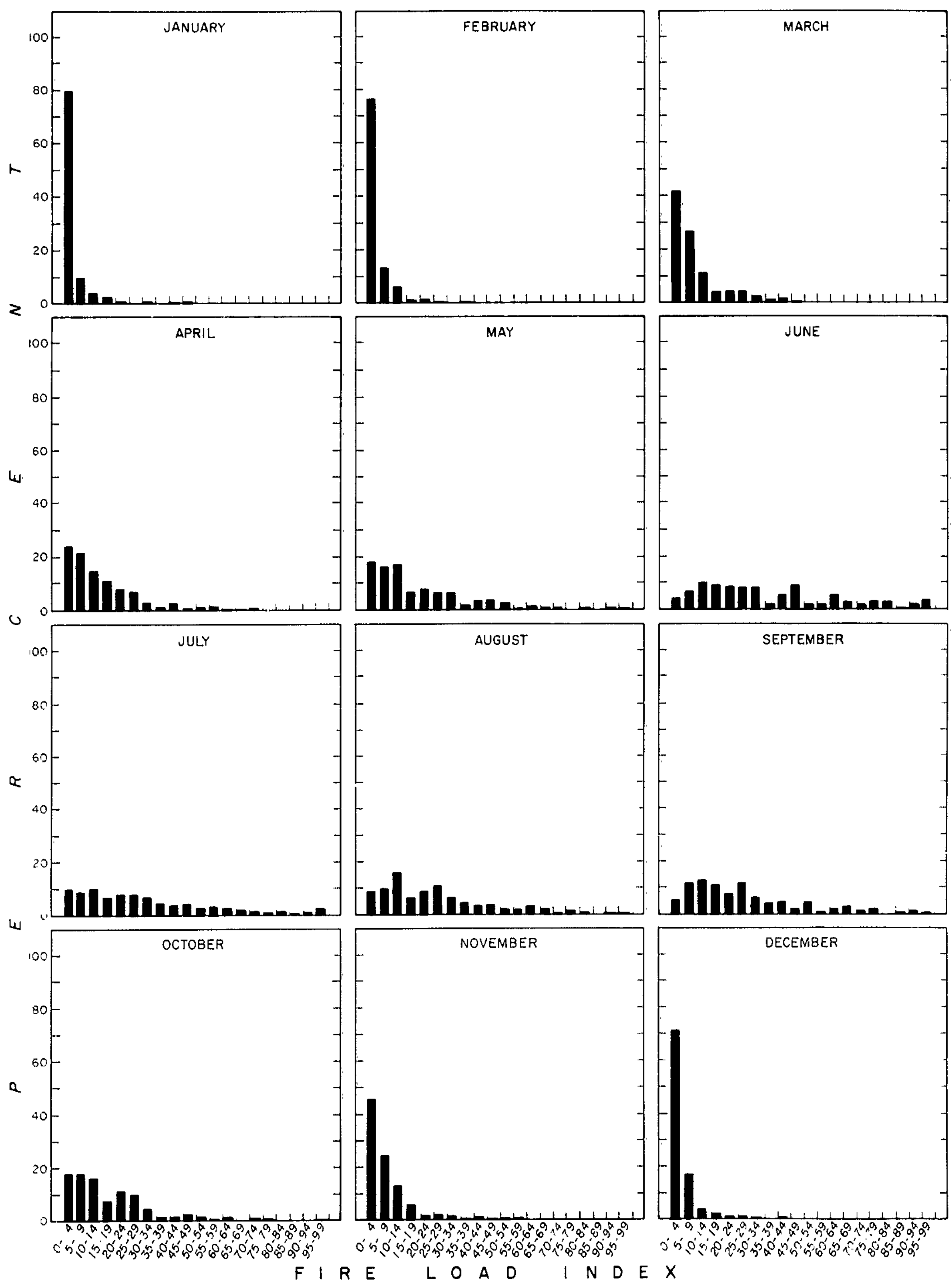
STATION 24128 WINNEMUCCA, NEVADA



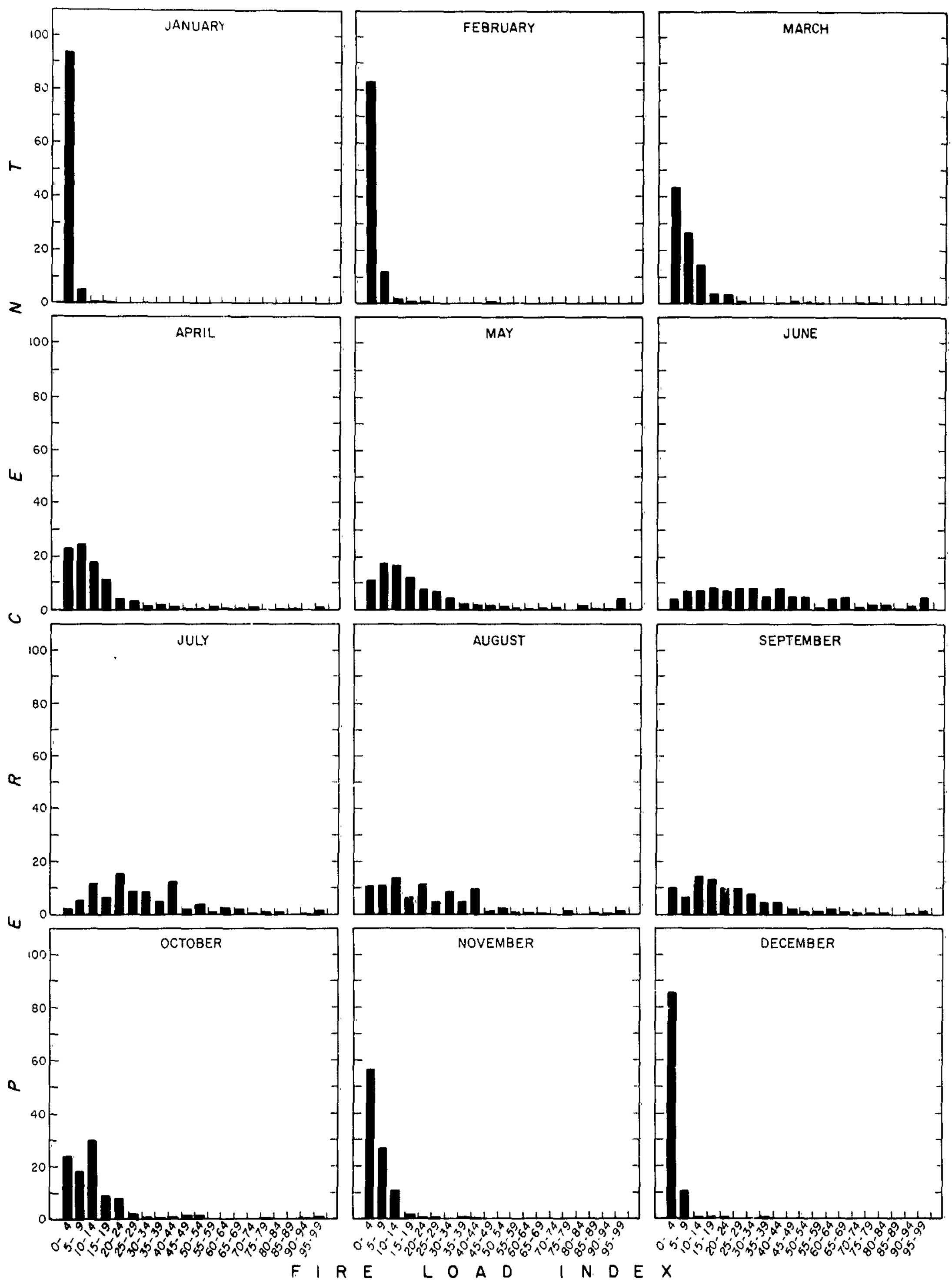
STATION 24127 SALT LAKE CITY, UTAH



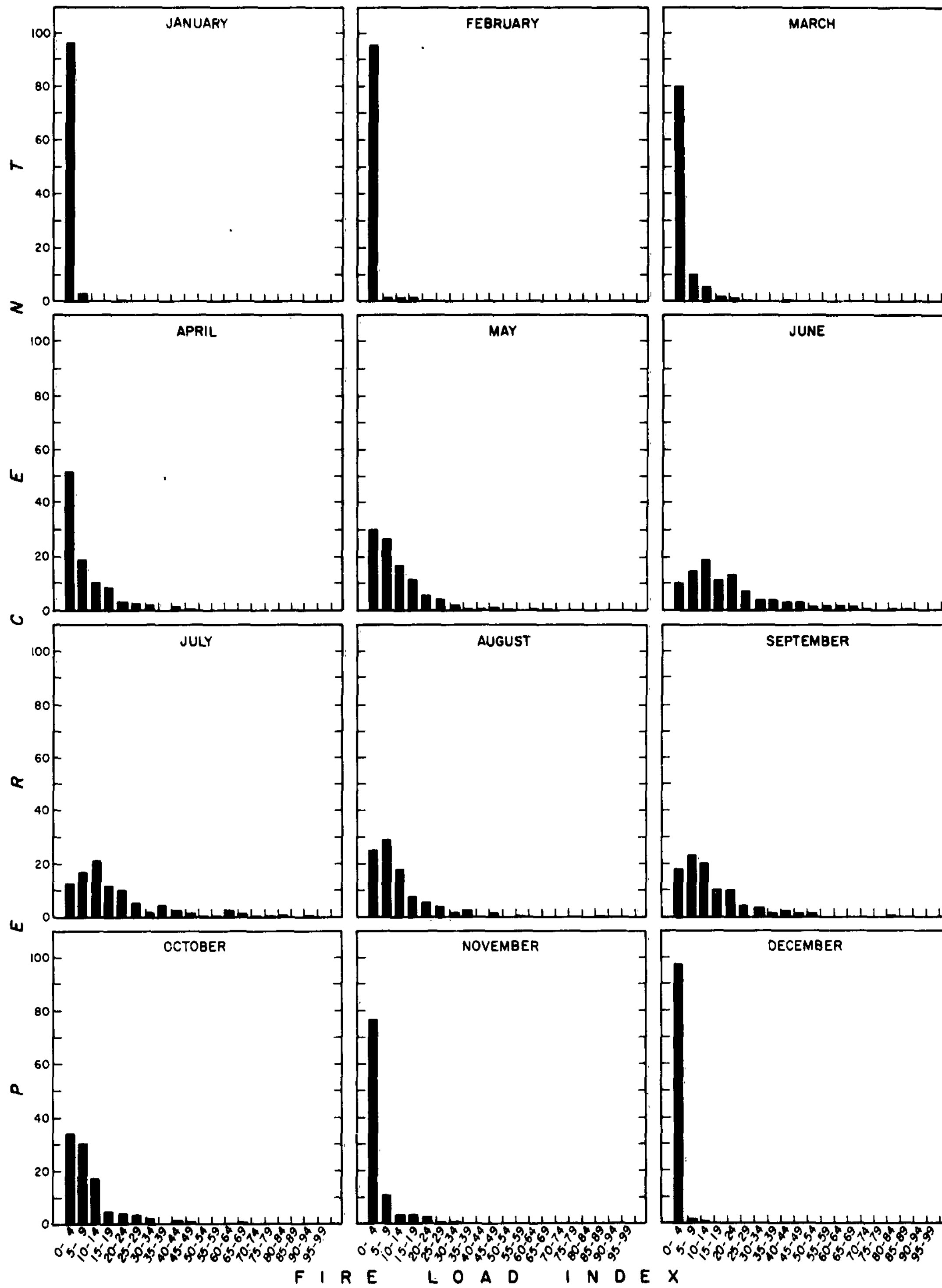
STATION 93129 CEDAR CITY, UTAH



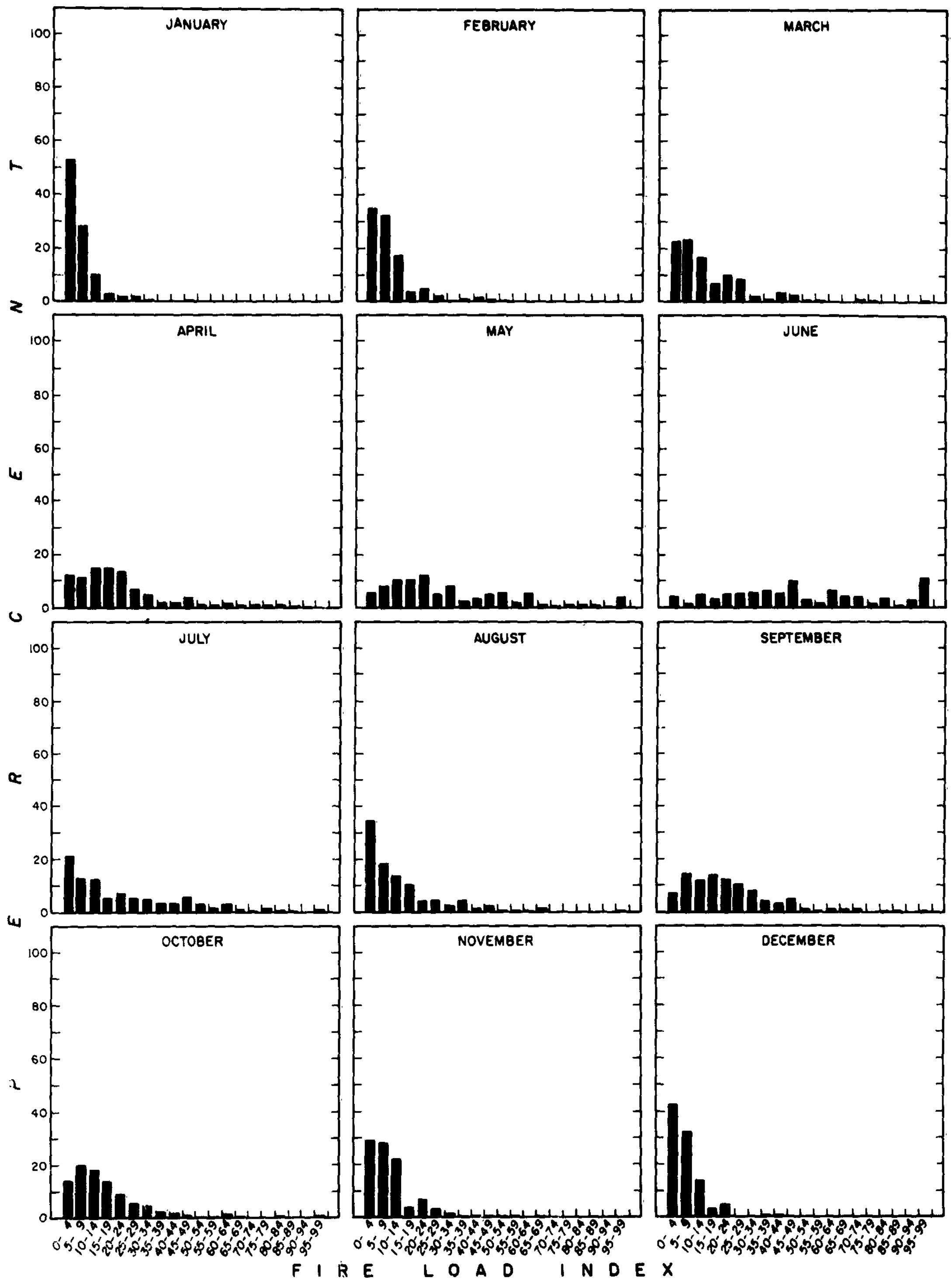
STATION 23066 GRAND JUNCTION, COLORADO



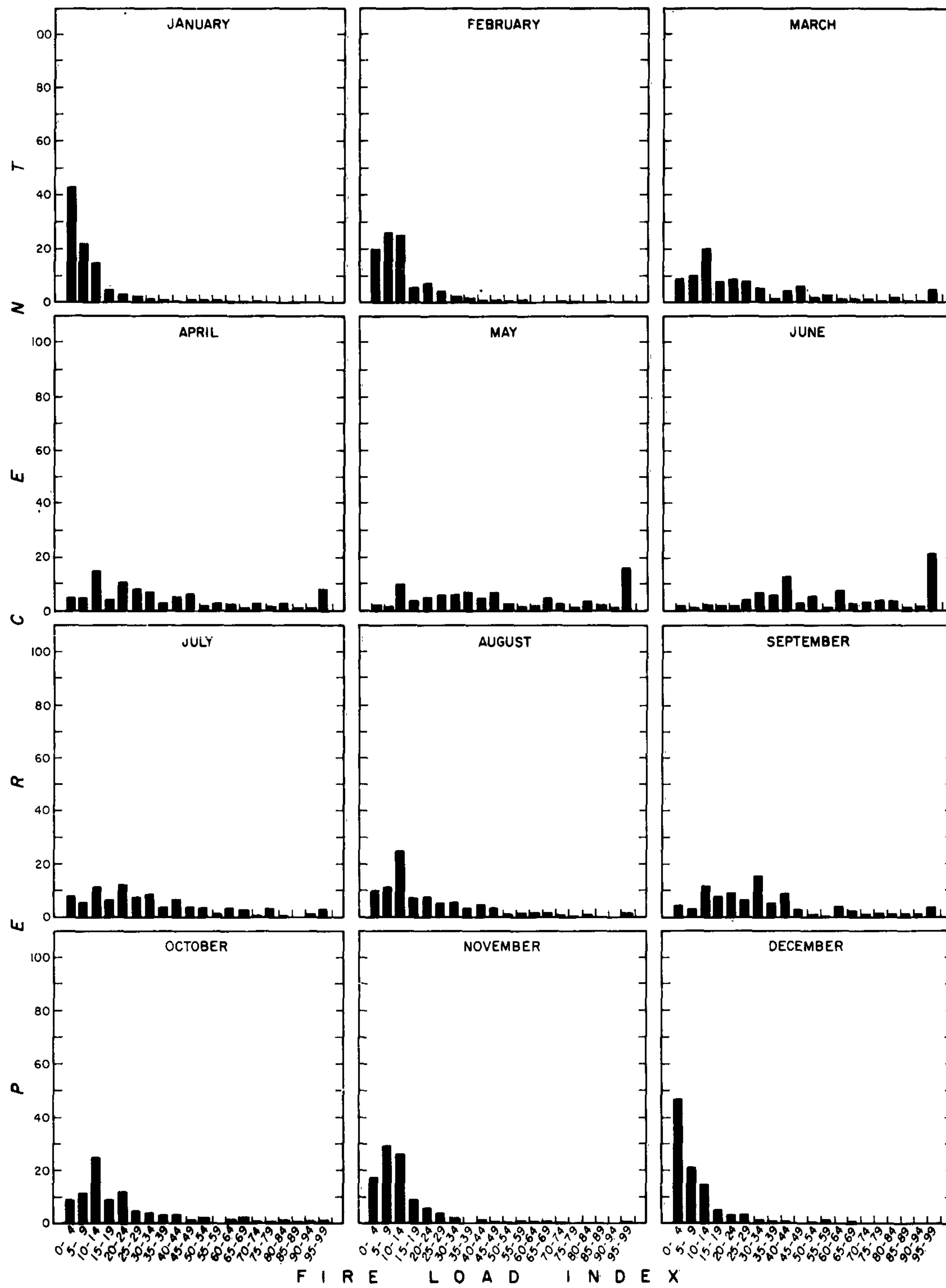
STATION 23063 EAGLE, COLORADO



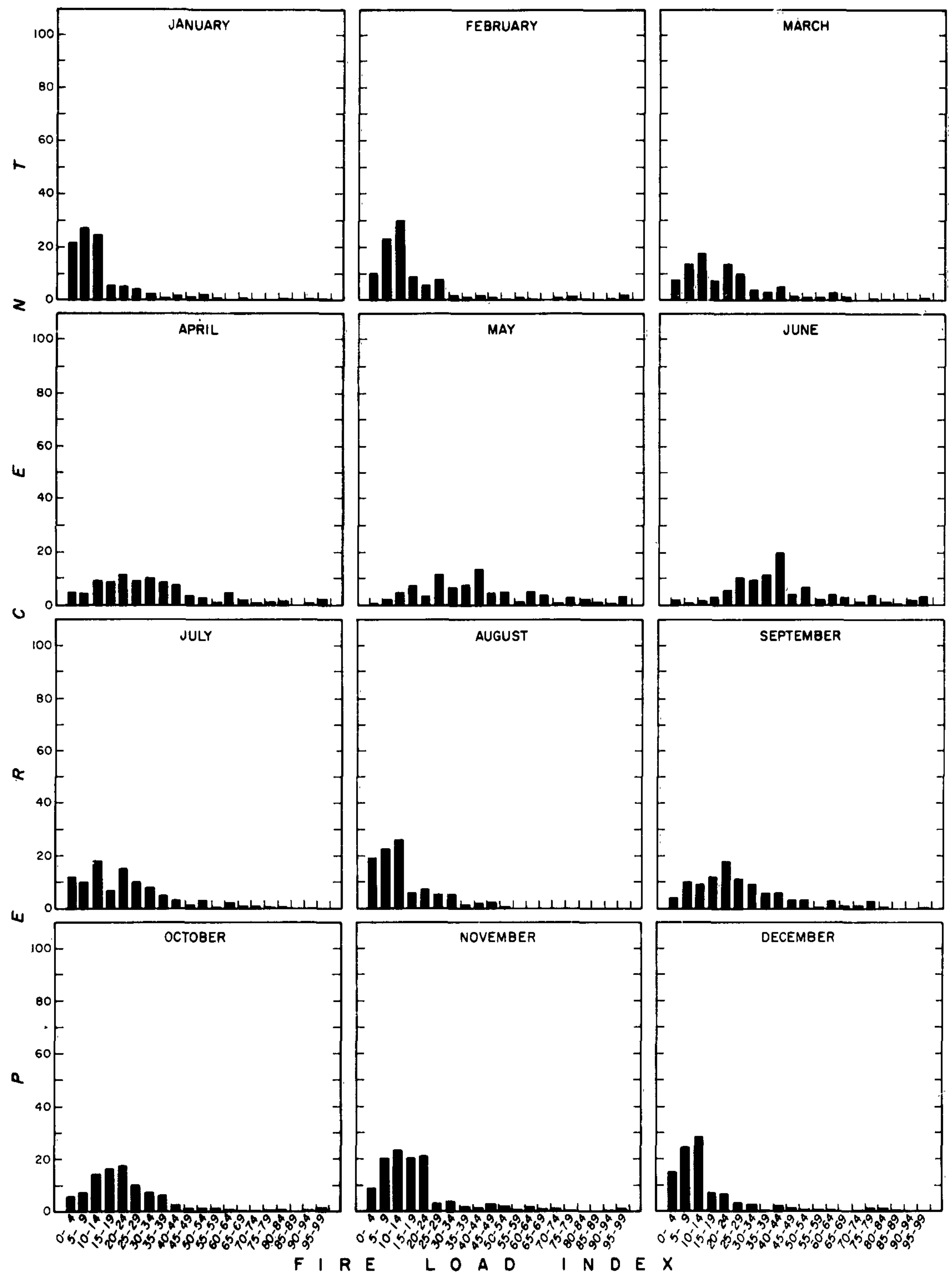
STATION 23184 PRESCOTT, ARIZONA



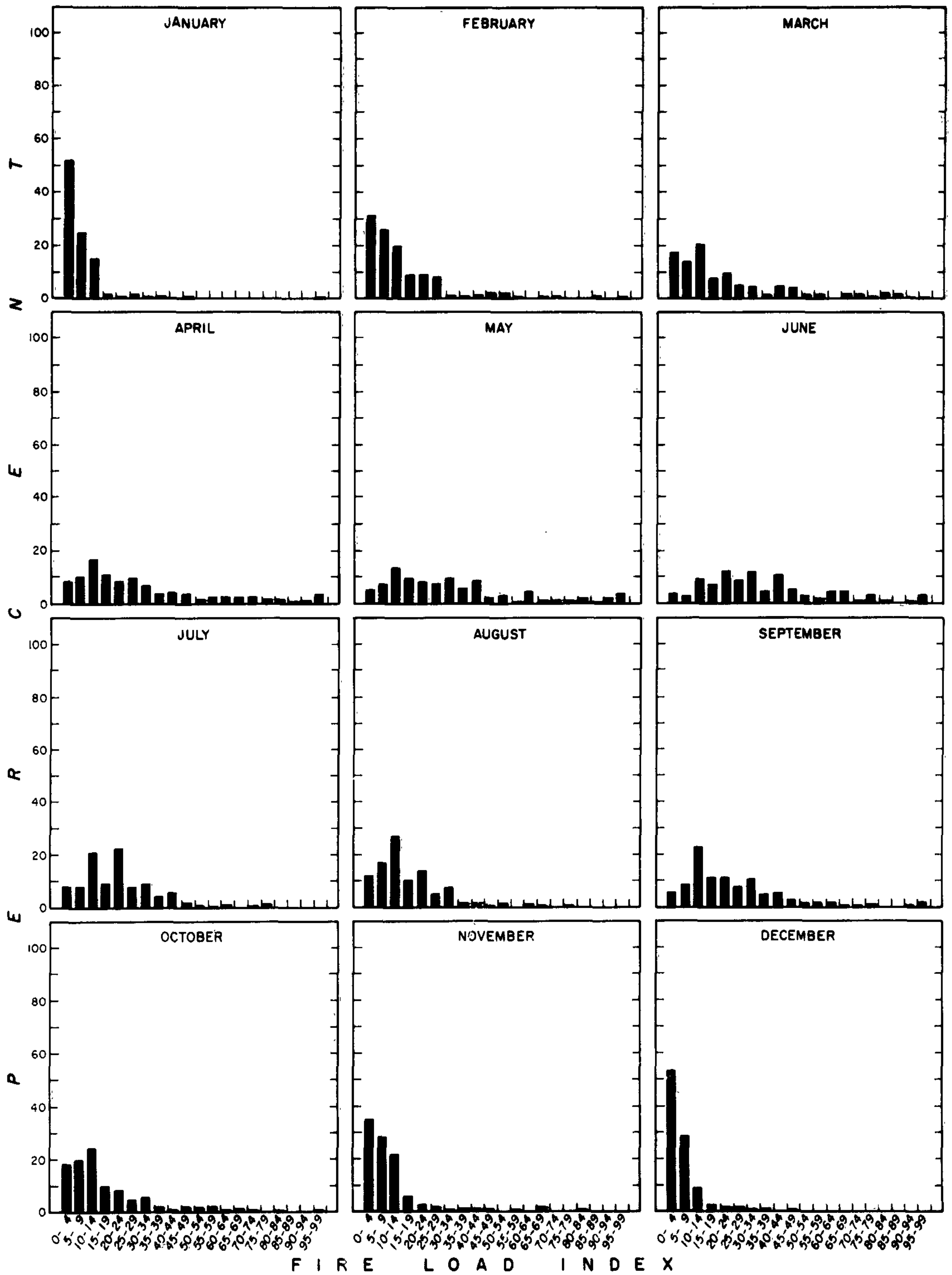
STATION 23194 WINSLOW, ARIZONA



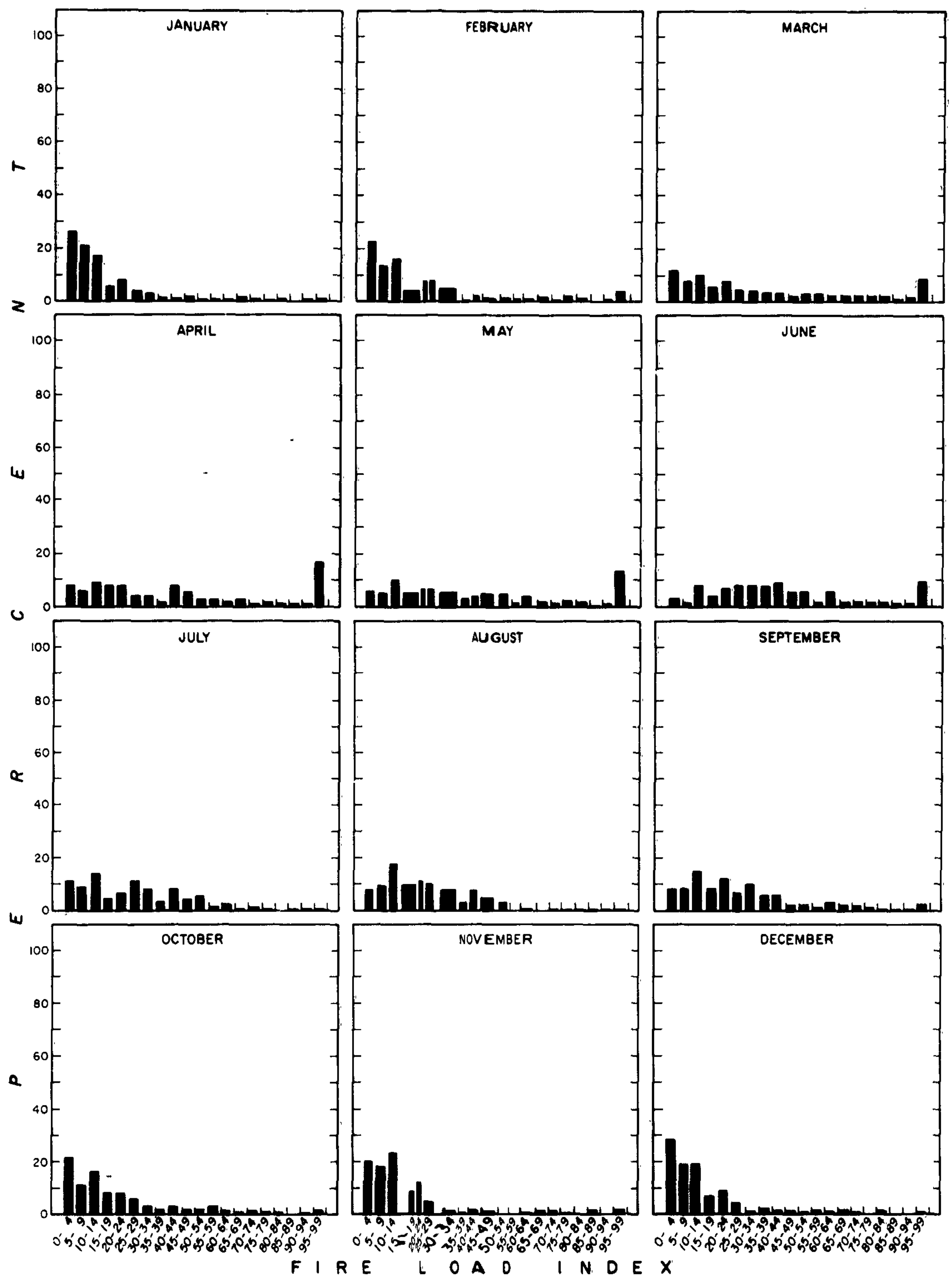
STATION 23160 TUCSON, ARIZONA



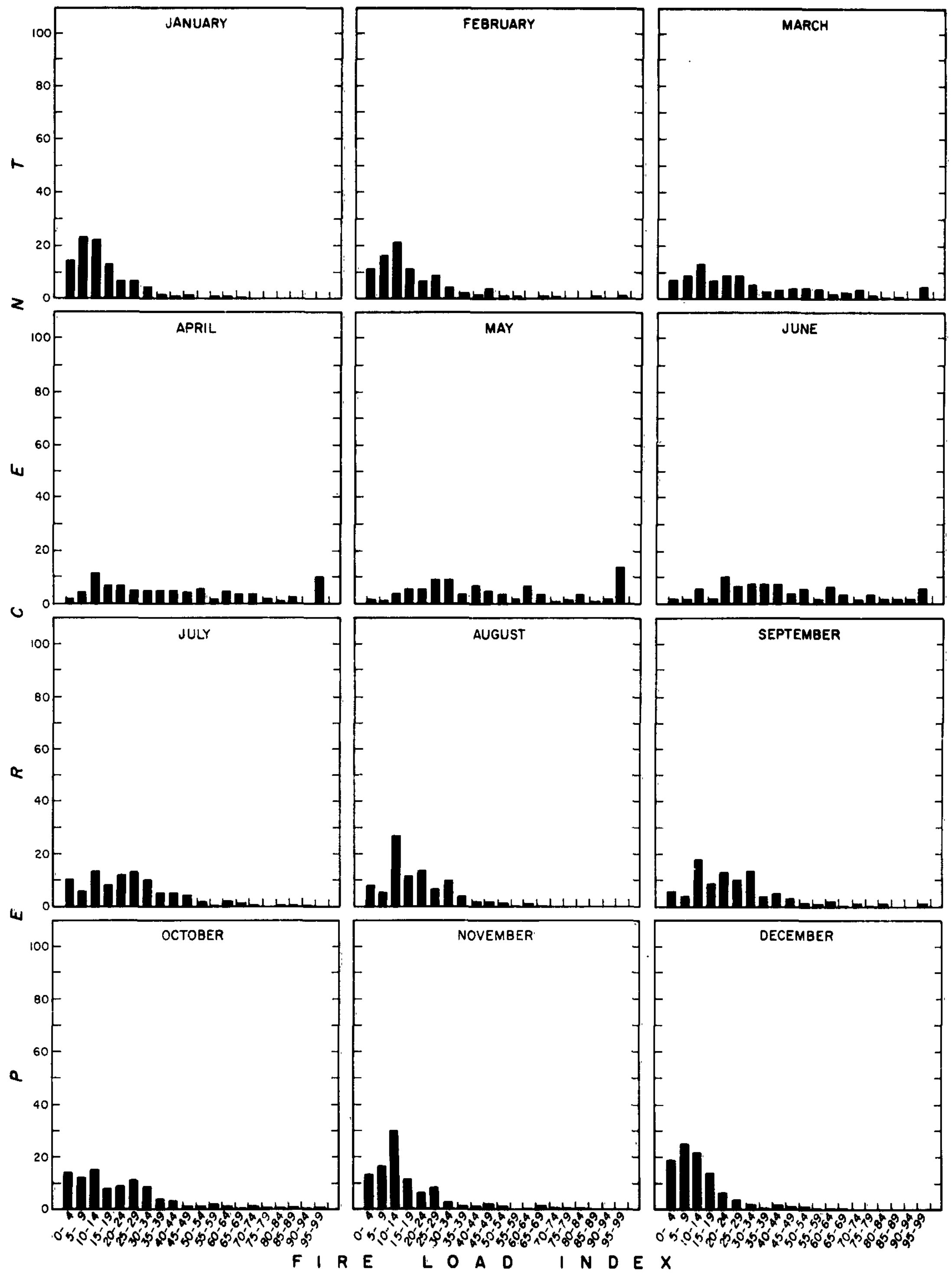
STATION 23050 ALBUQUERQUE, NEW MEXICO



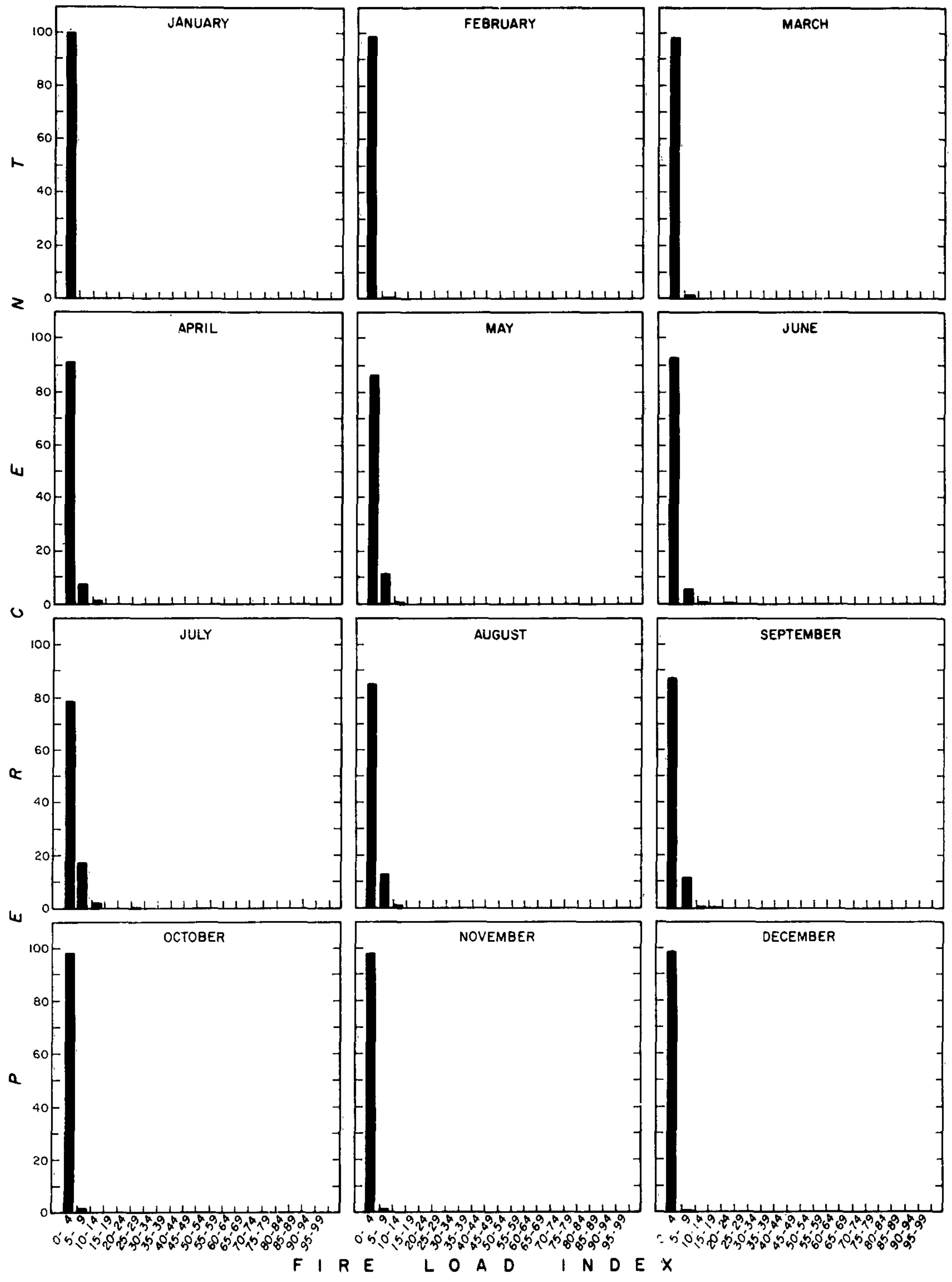
STATION 23043 ROSWELL, NEW MEXICO



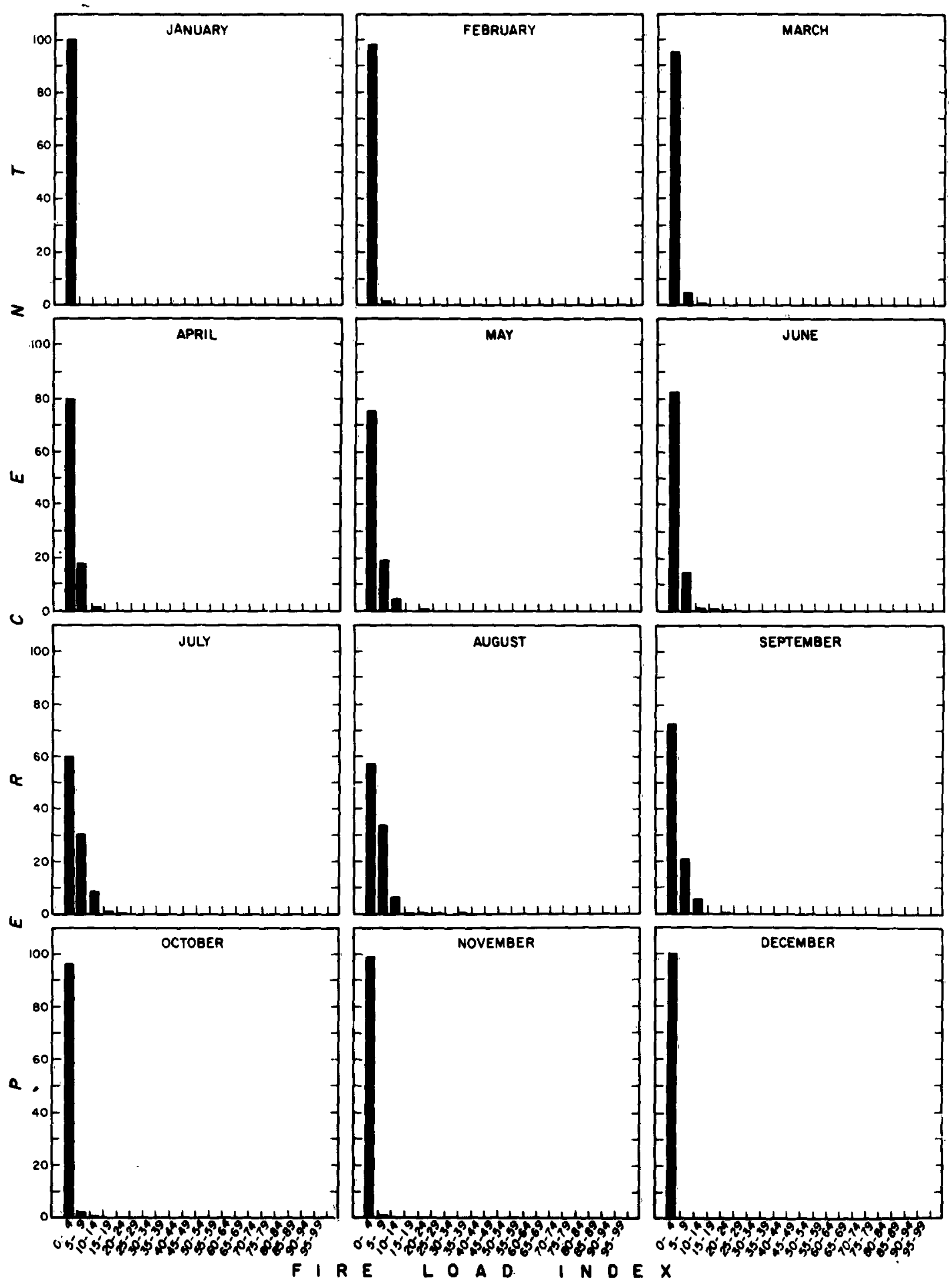
STATION 23044 EL PASO, TEXAS



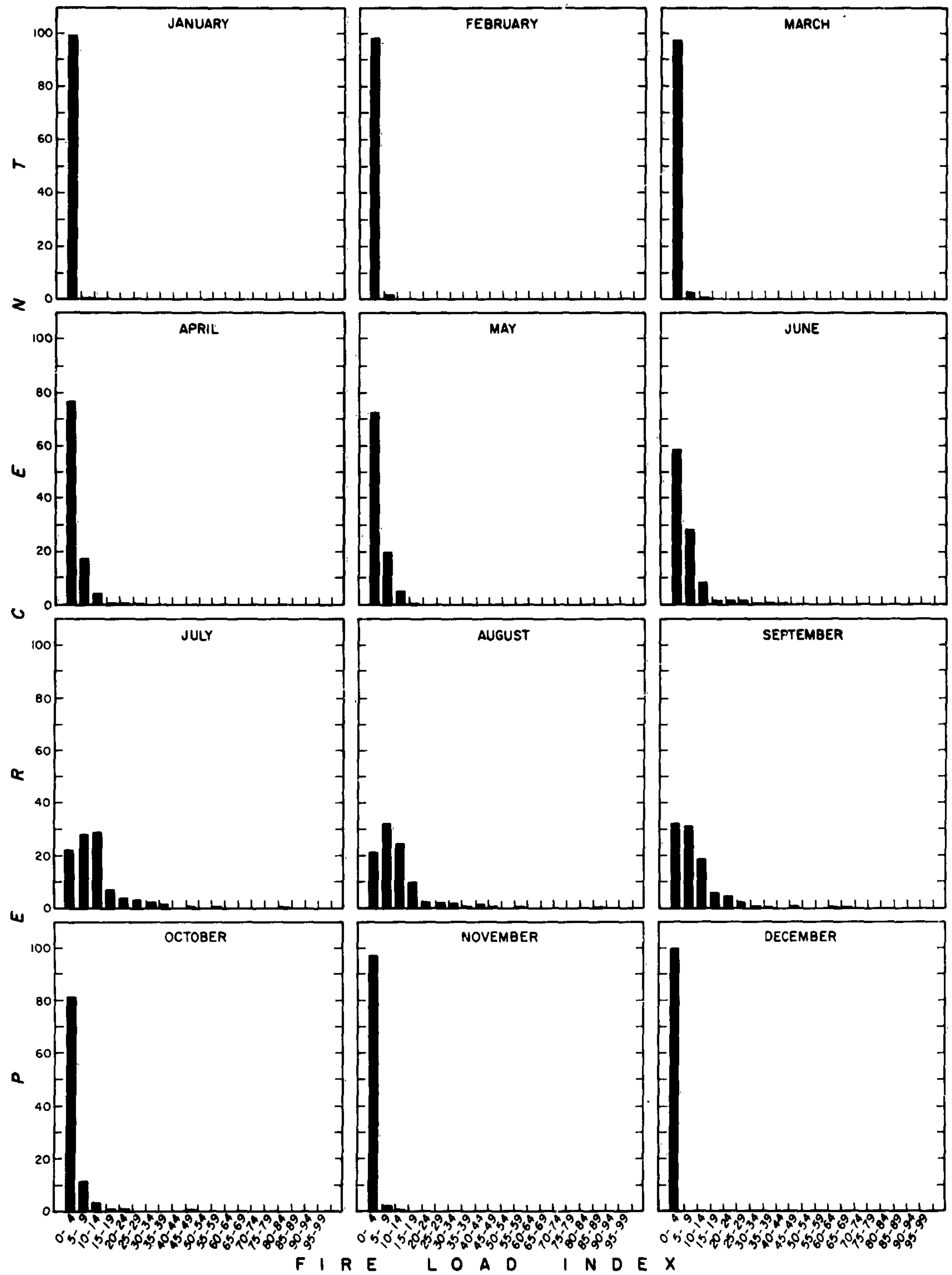
STATION 24244 SEATTLE, WASHINGTON



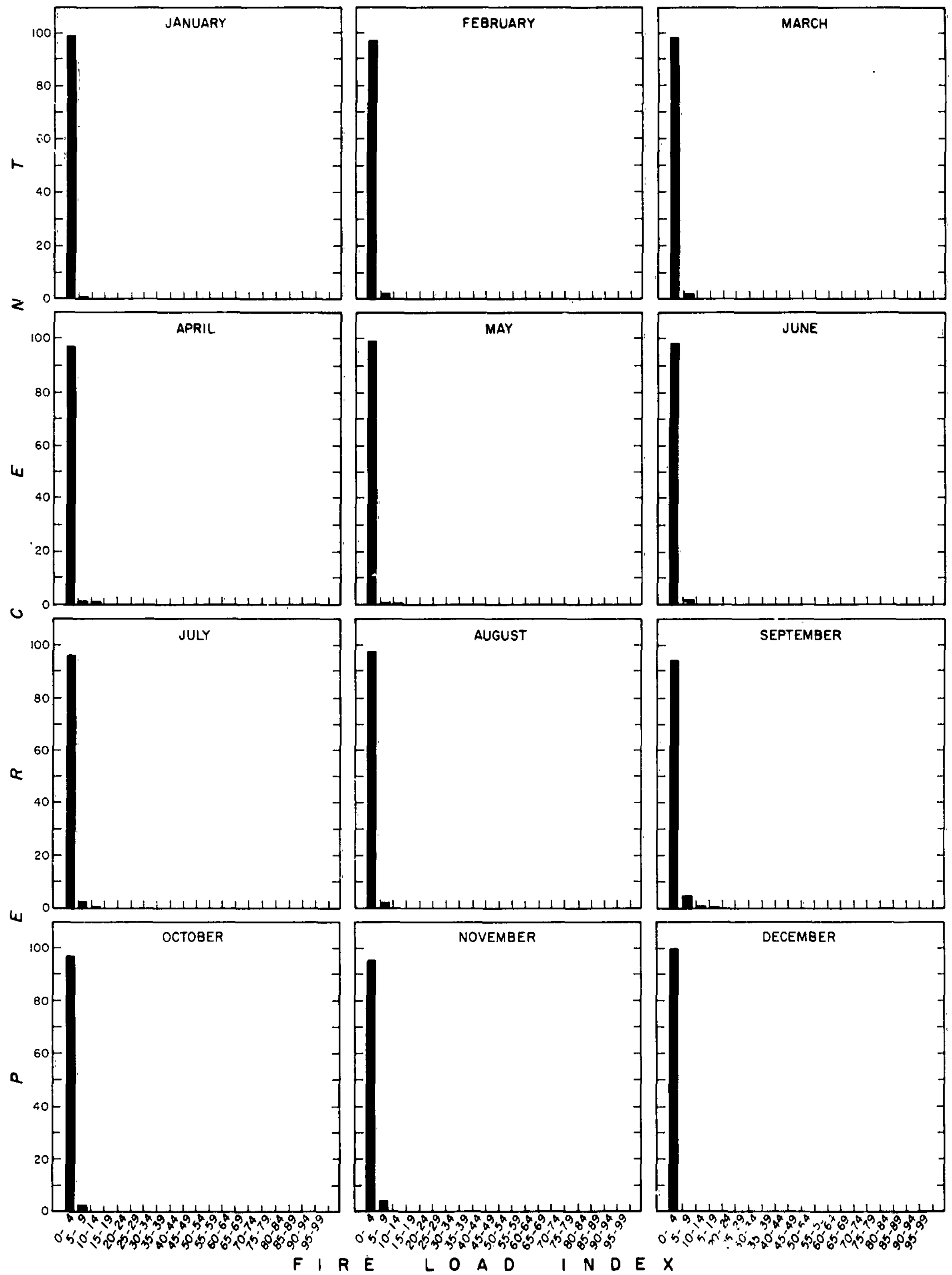
STATION 24227 OLYMPIA, WASHINGTON



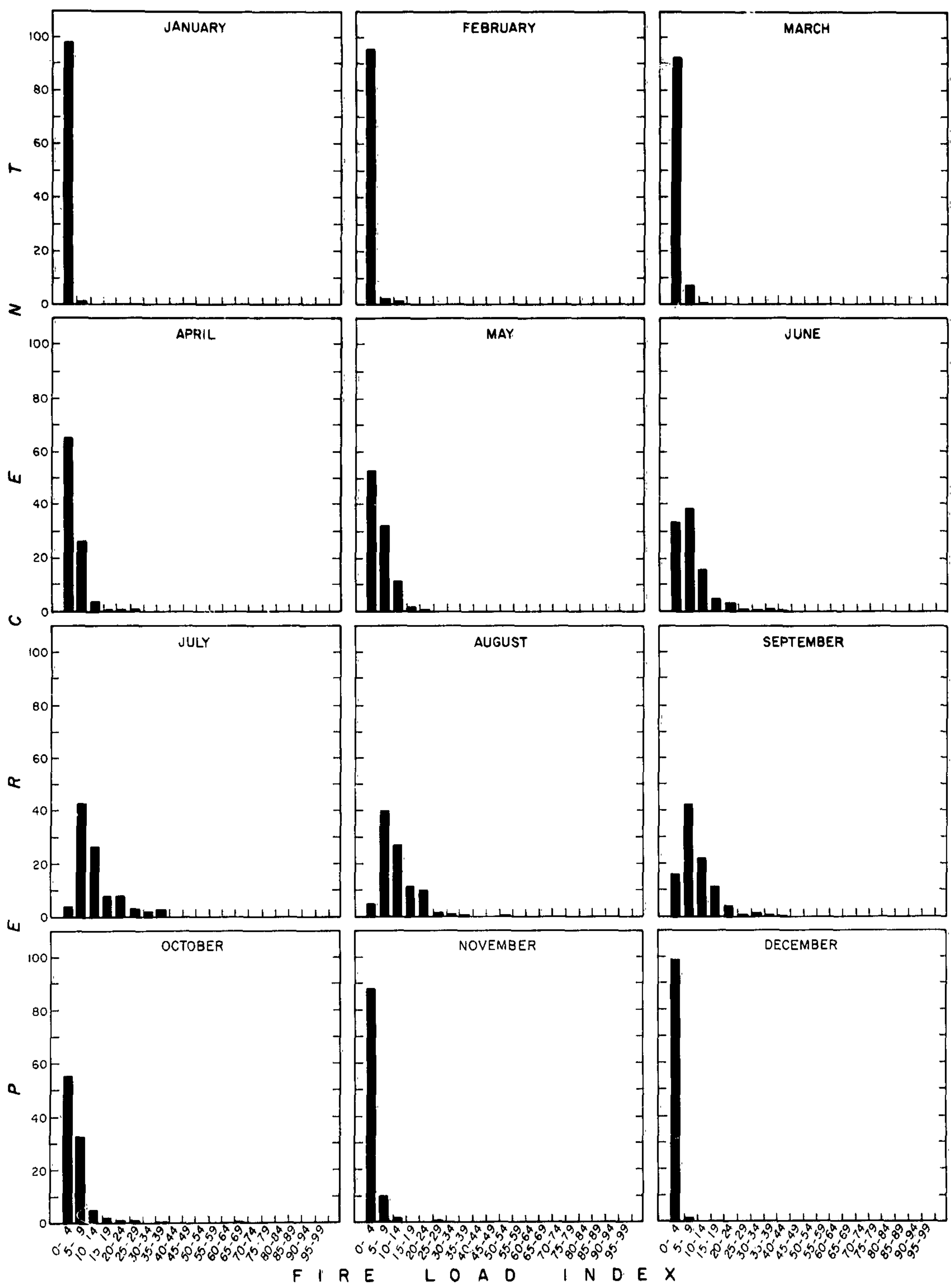
STATION 24221 EUGENE, OREGON



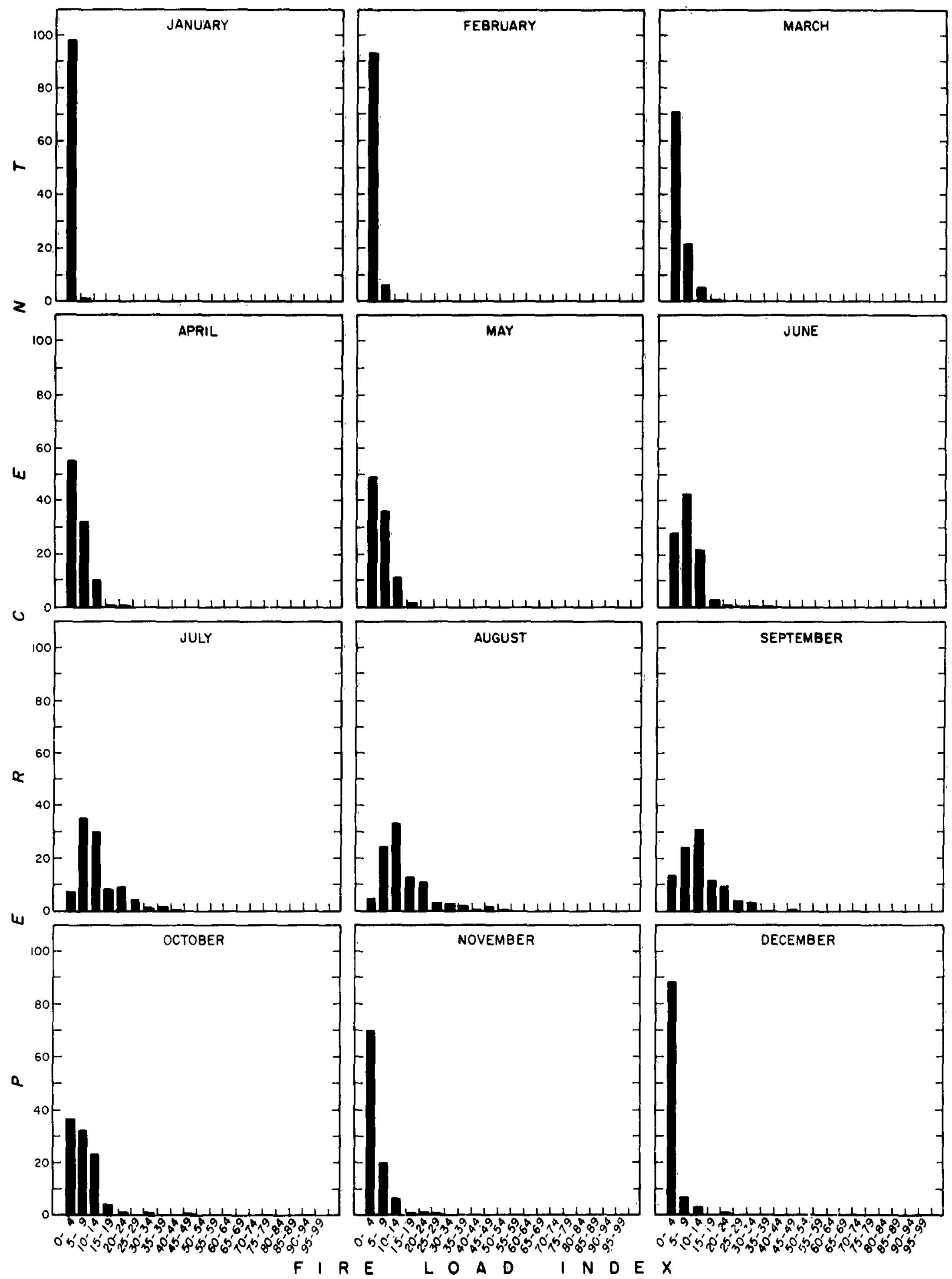
STATION 24284 NORTH BEND, OREGON



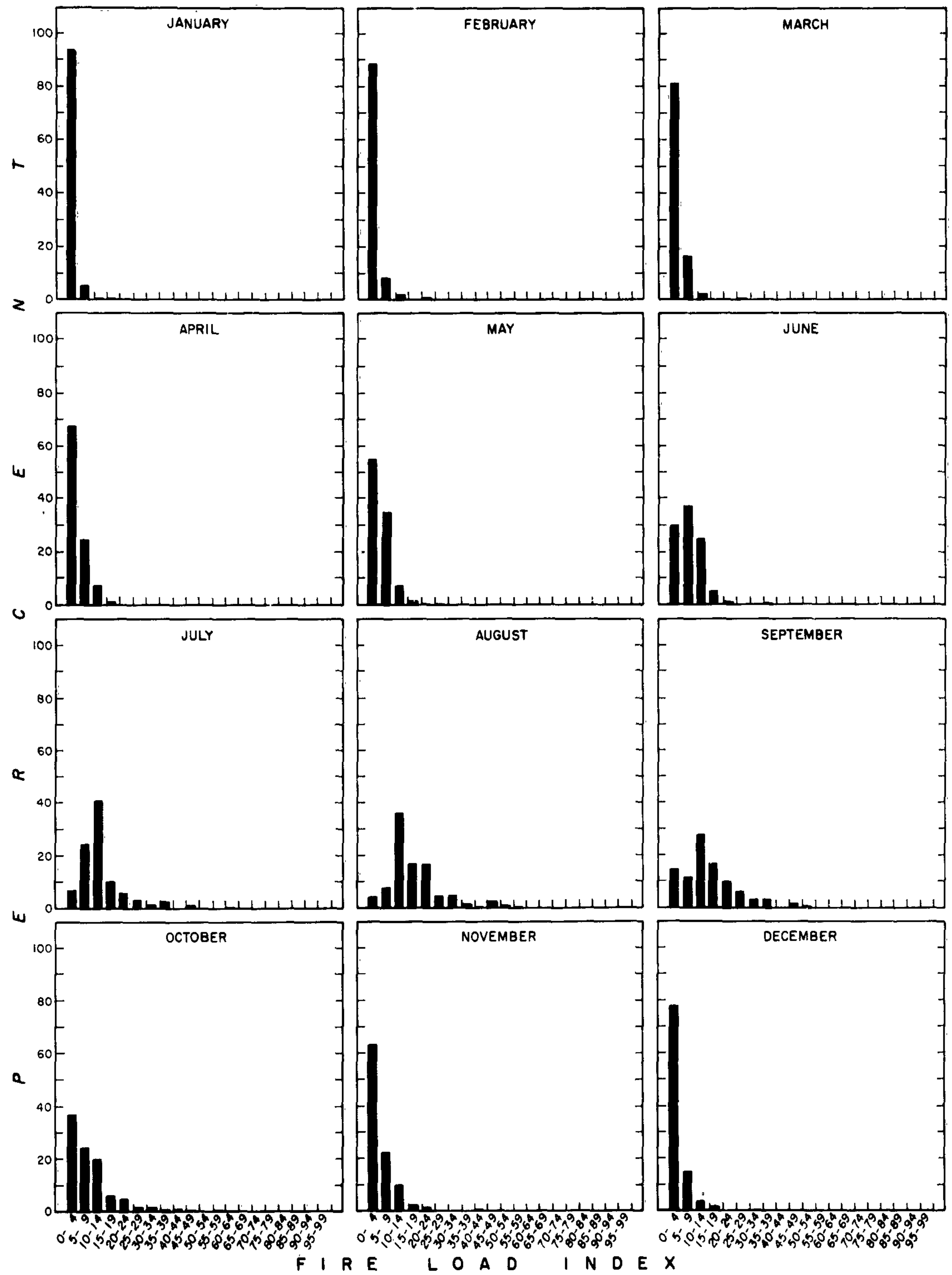
STATION 24225 MEDFORD, OREGON



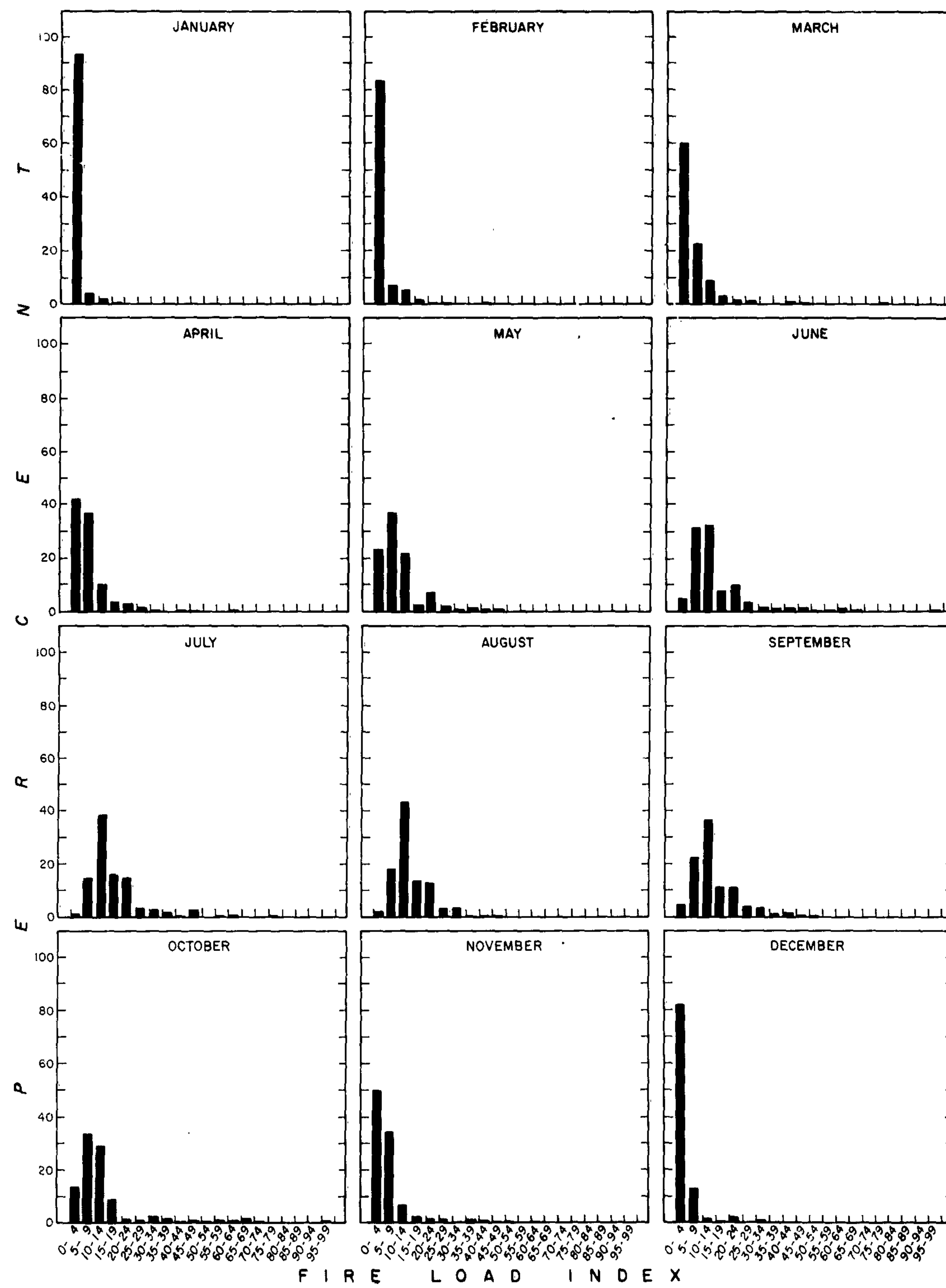
STATION 24215 MT. SHASTA, CALIFORNIA



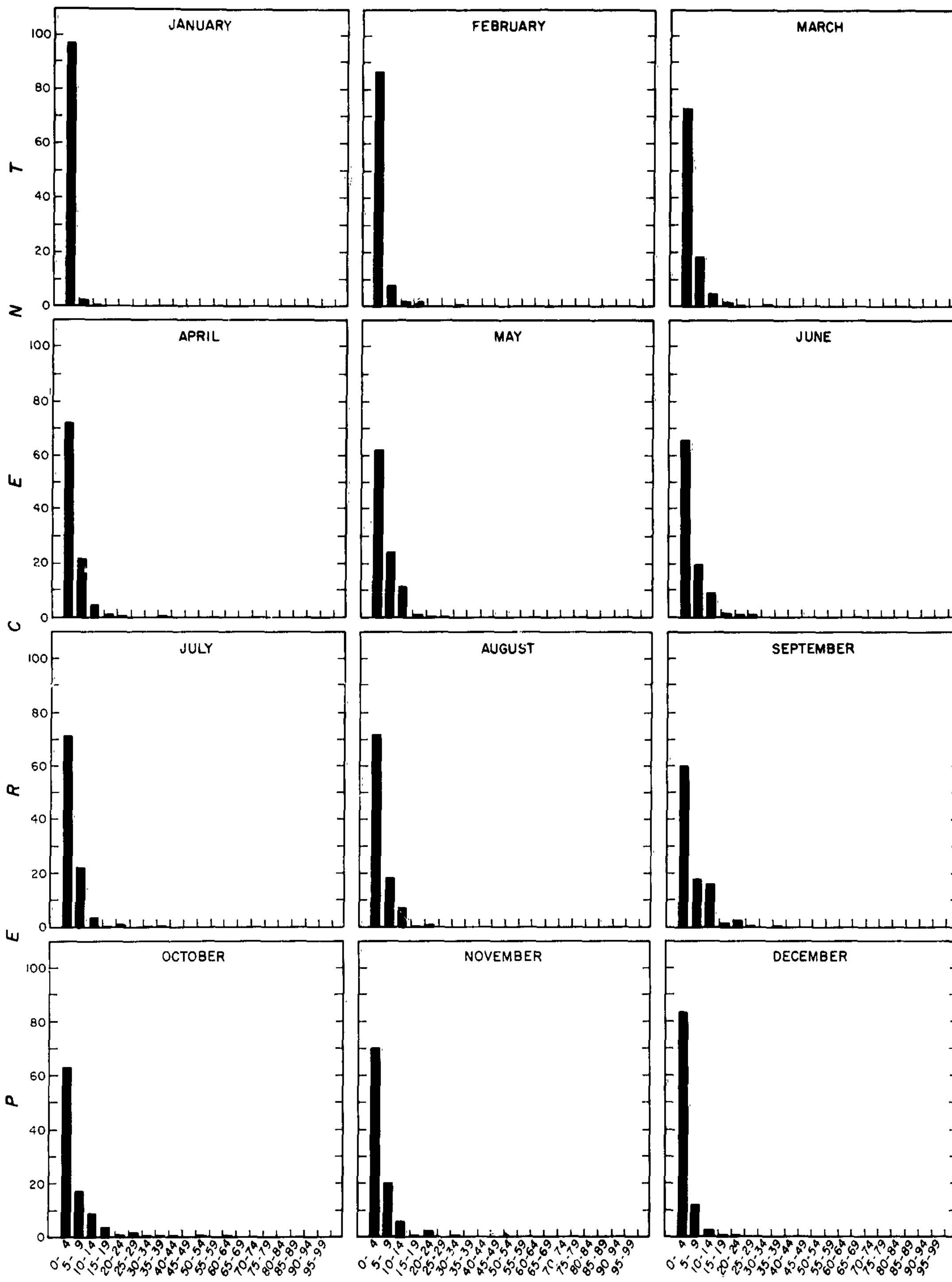
STATION 23225 BLUE CANYON, CALIFORNIA



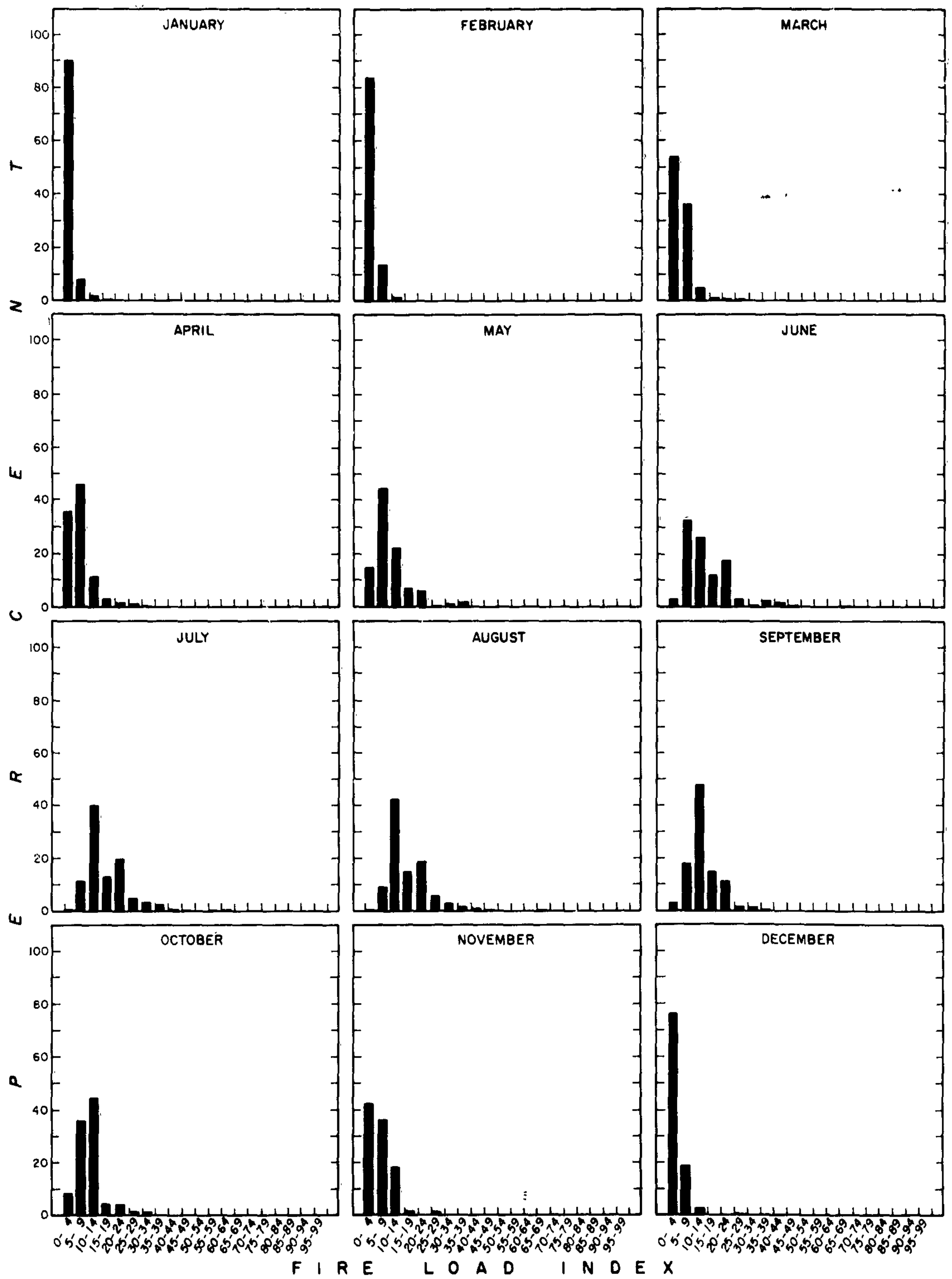
STATION 23232 SACRAMENTO, CALIFORNIA



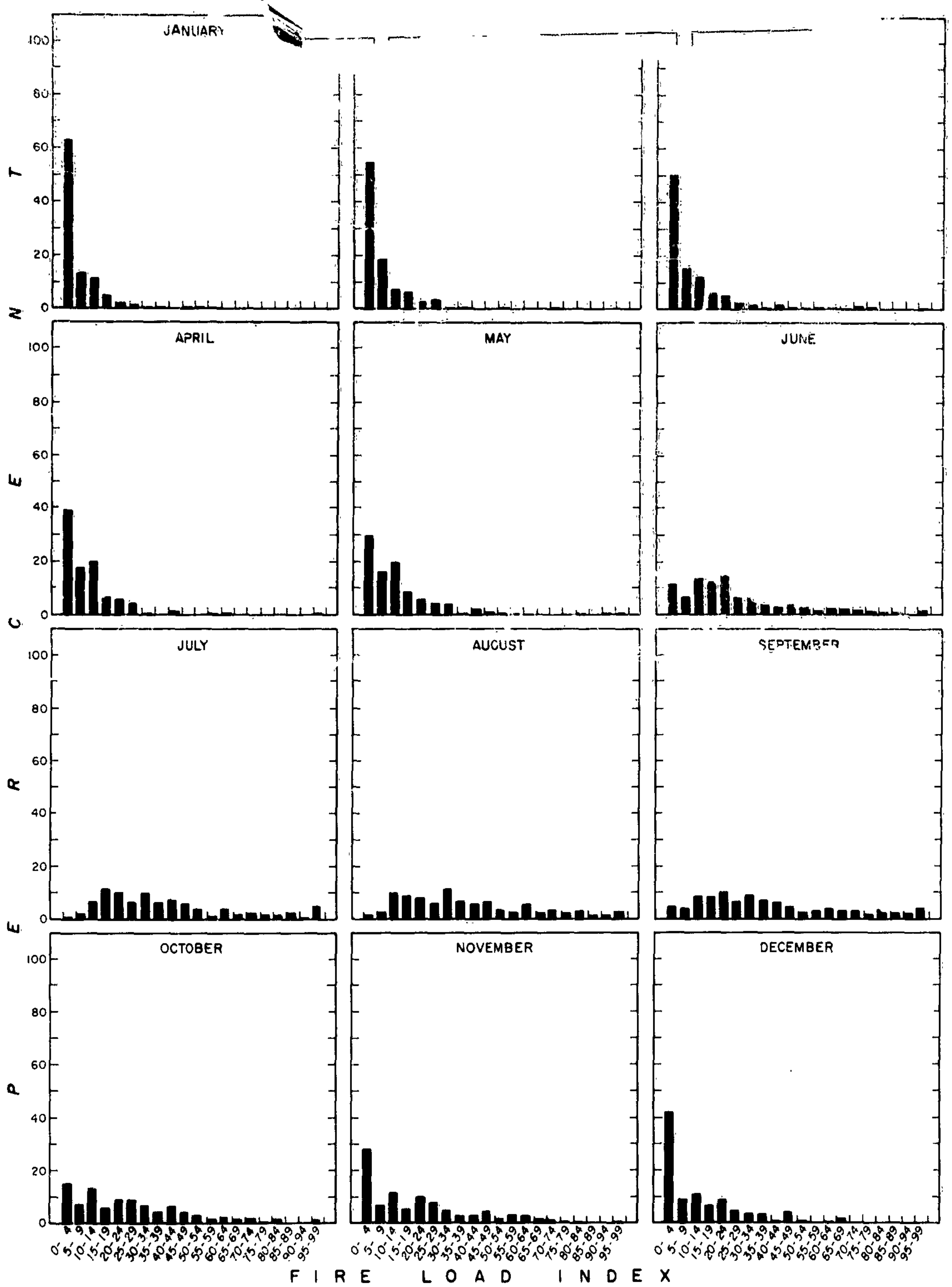
STATION 23230 OAKLAND, CALIFORNIA



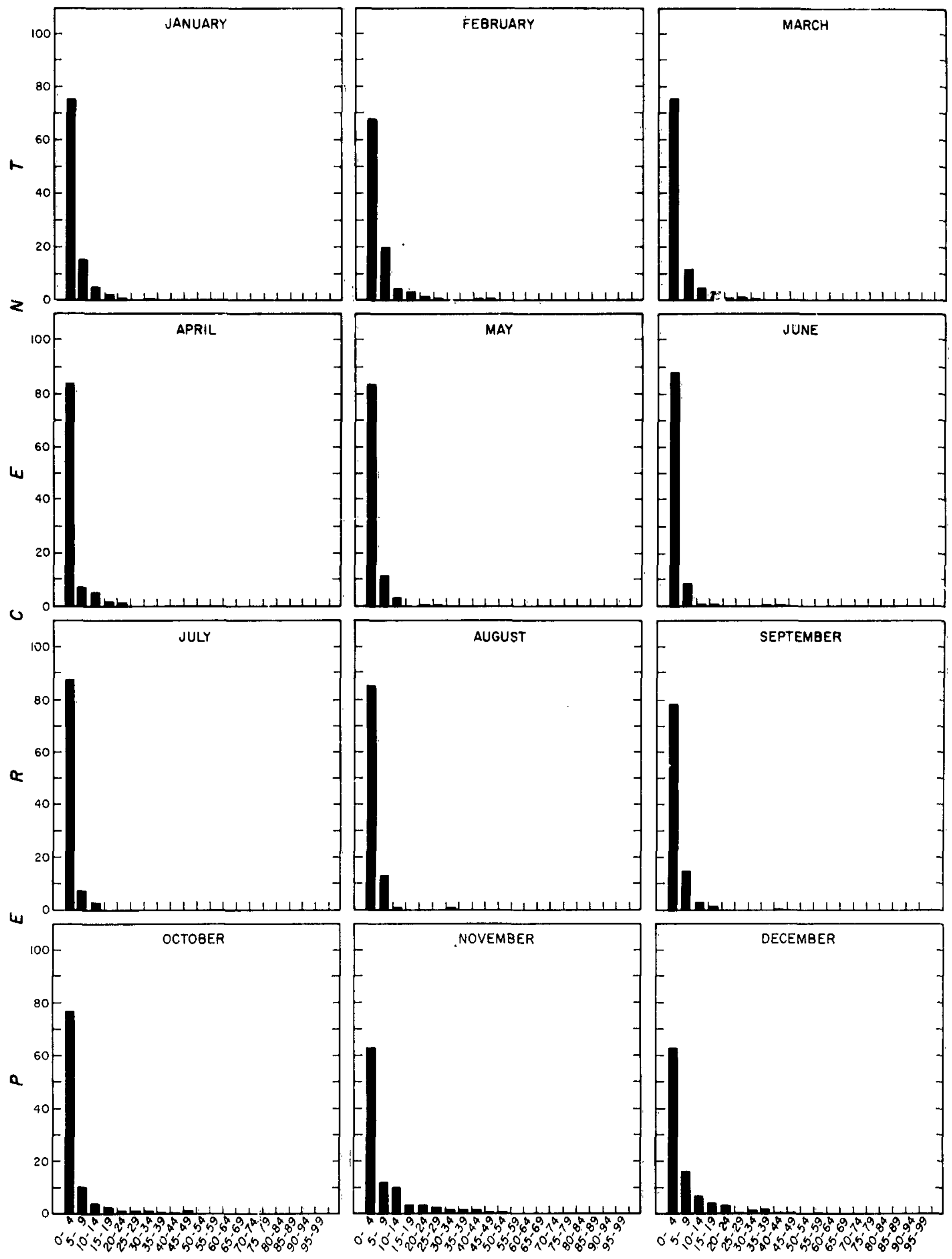
STATION 93193 FRESNO, CALIFORNIA



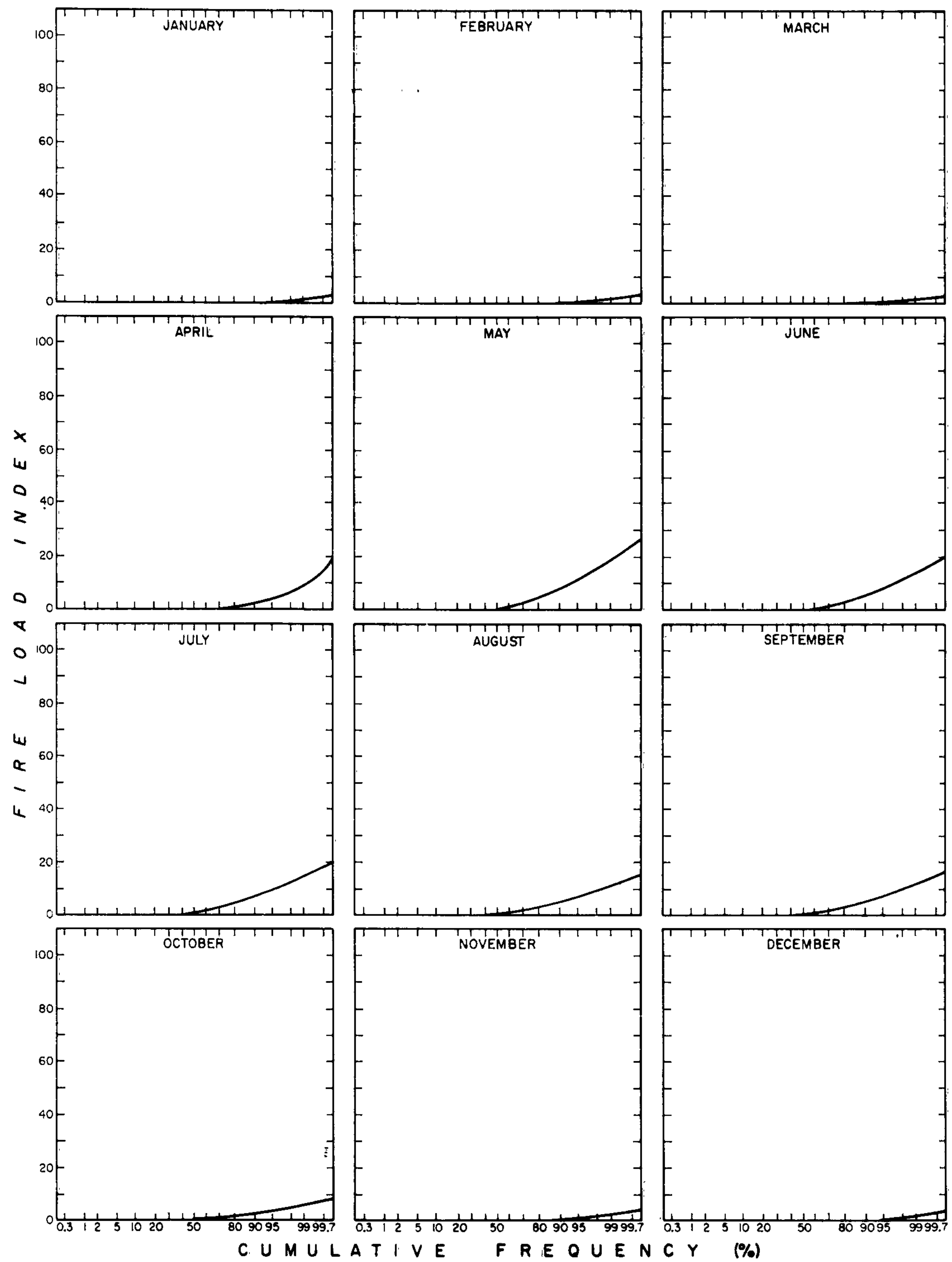
STATION 23187 SANDBERG, CALIFORNIA



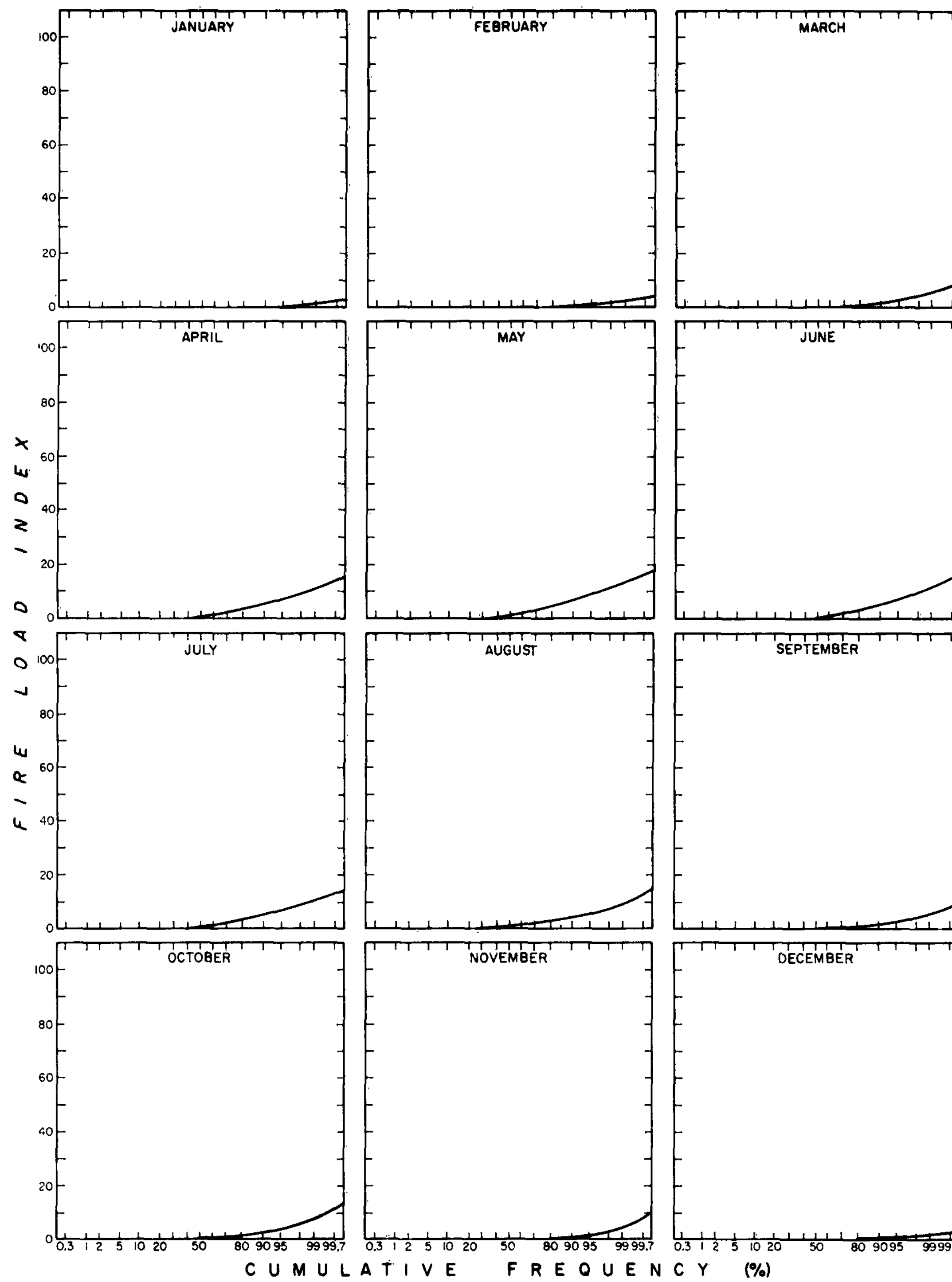
STATION 23174 LOS ANGELES, CALIFORNIA



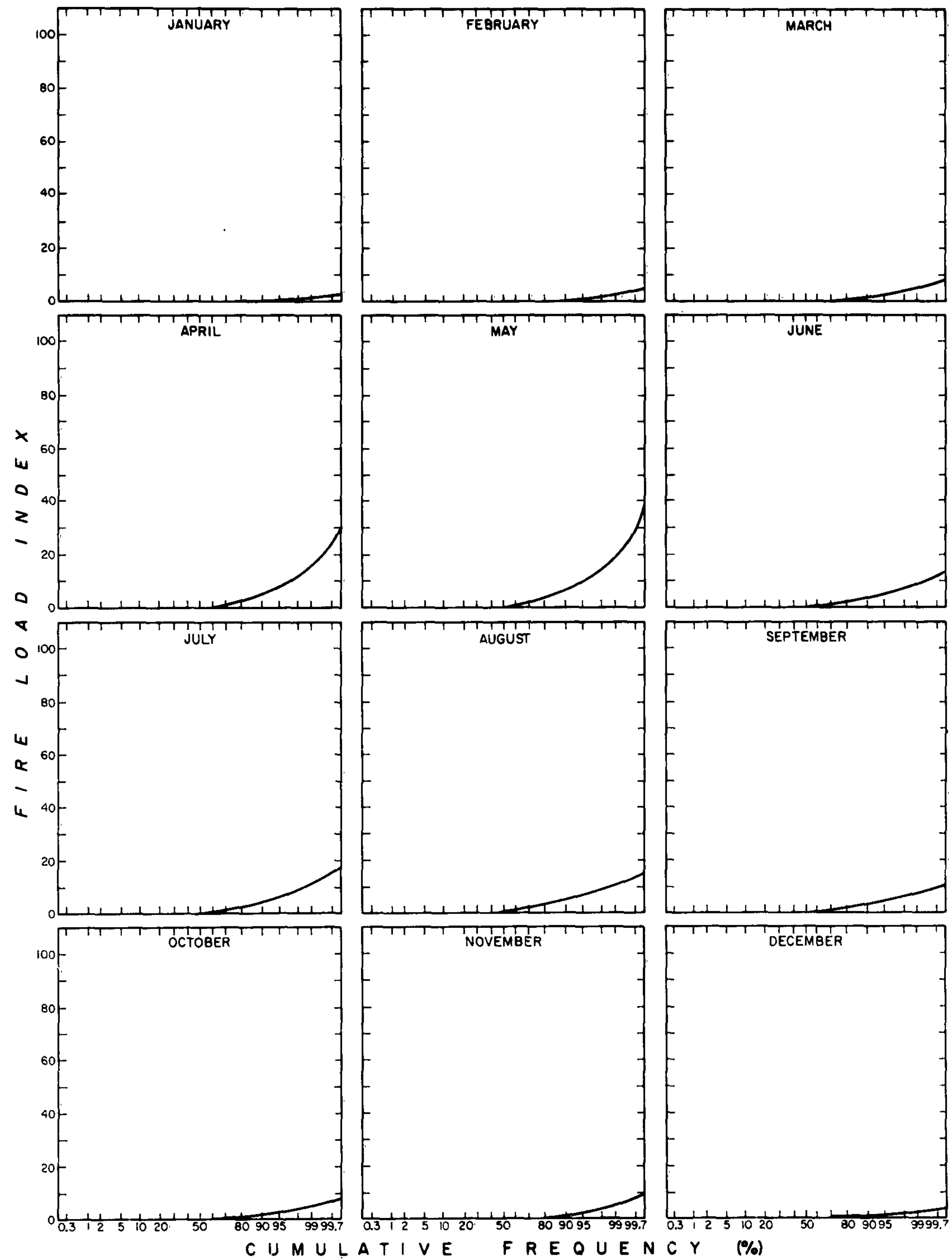
STATION 14607 CARIBOU, MAINE



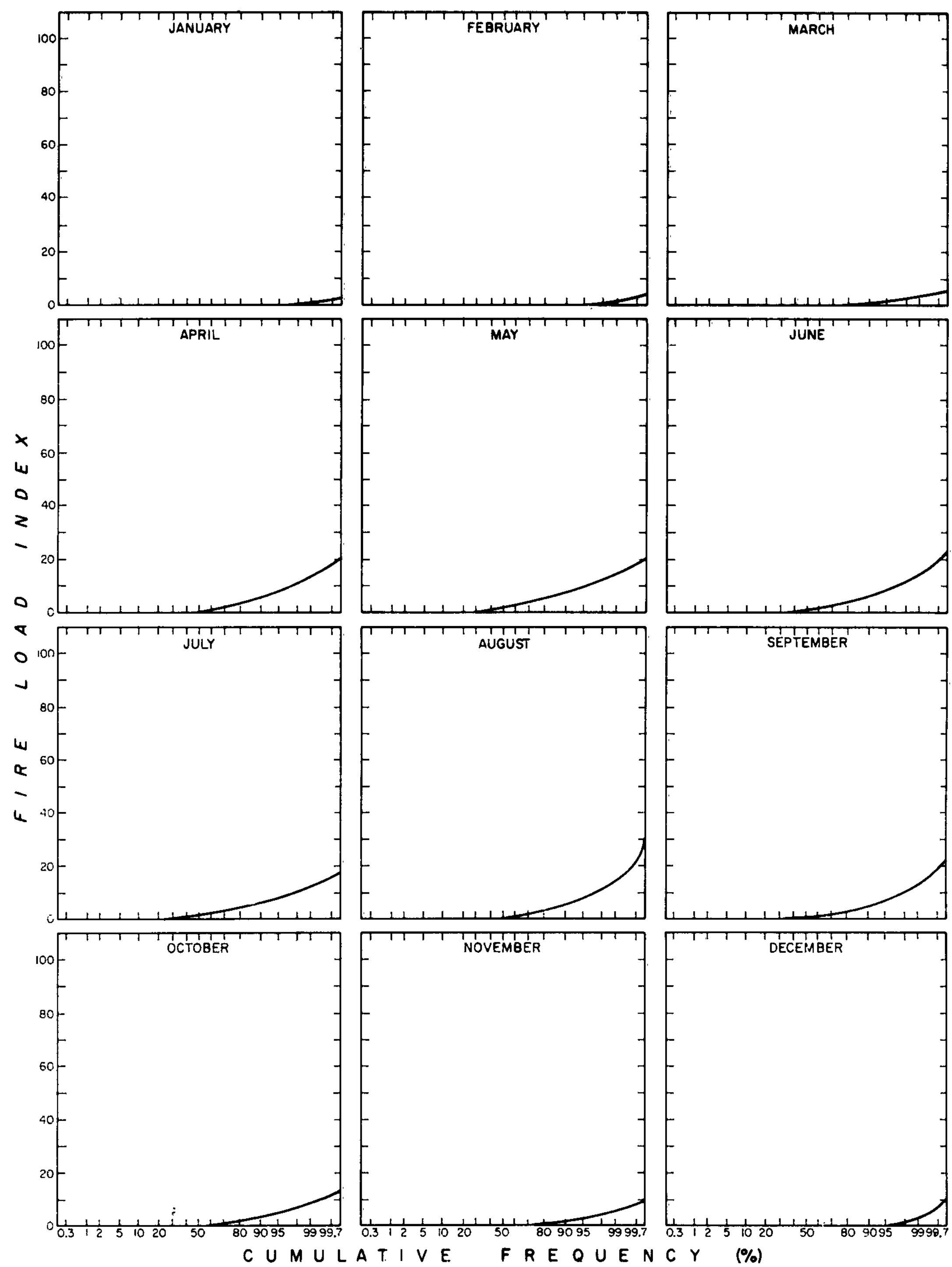
STATION 14742 BURLINGTON, VERMONT



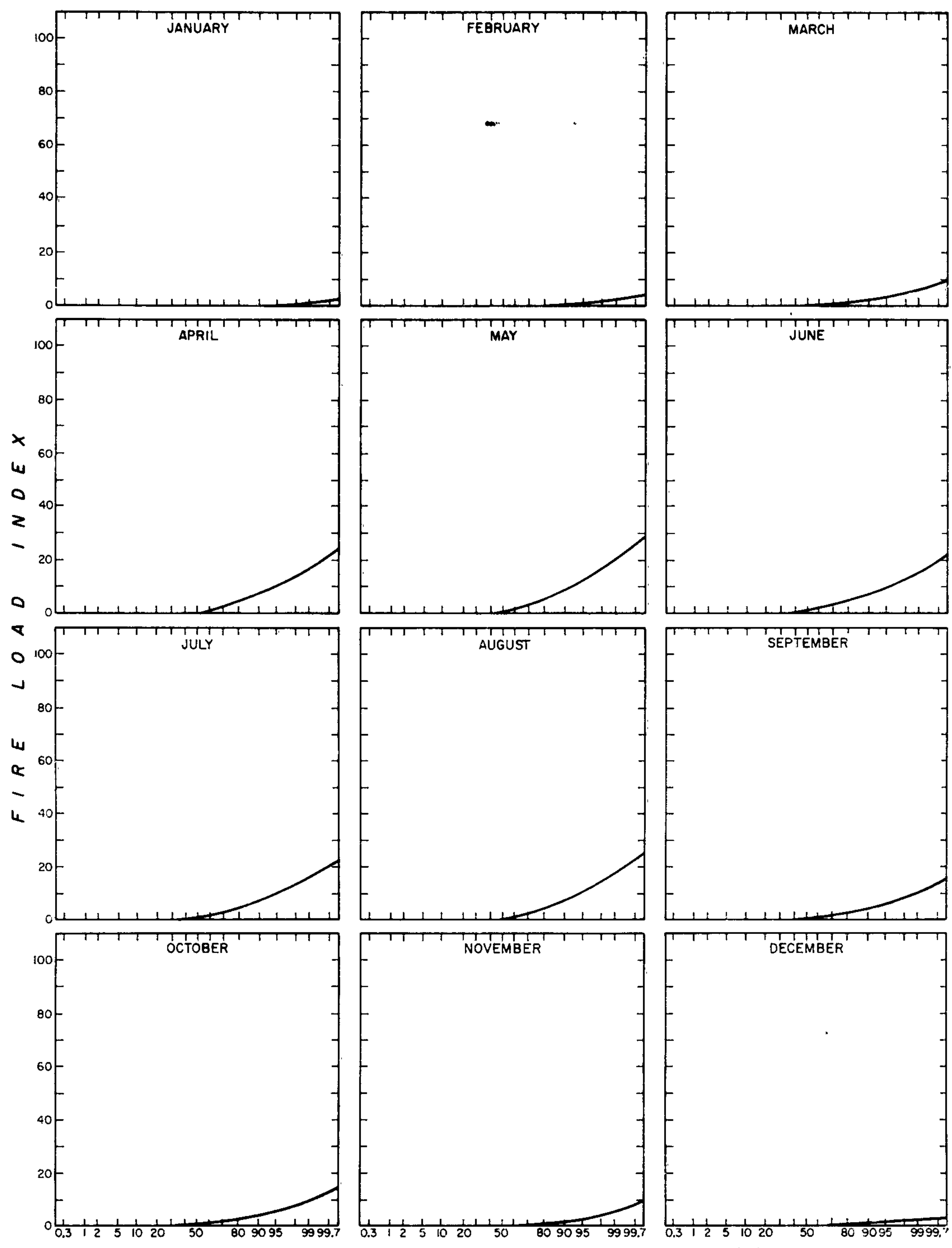
STATION 14764 PORTLAND, MAINE



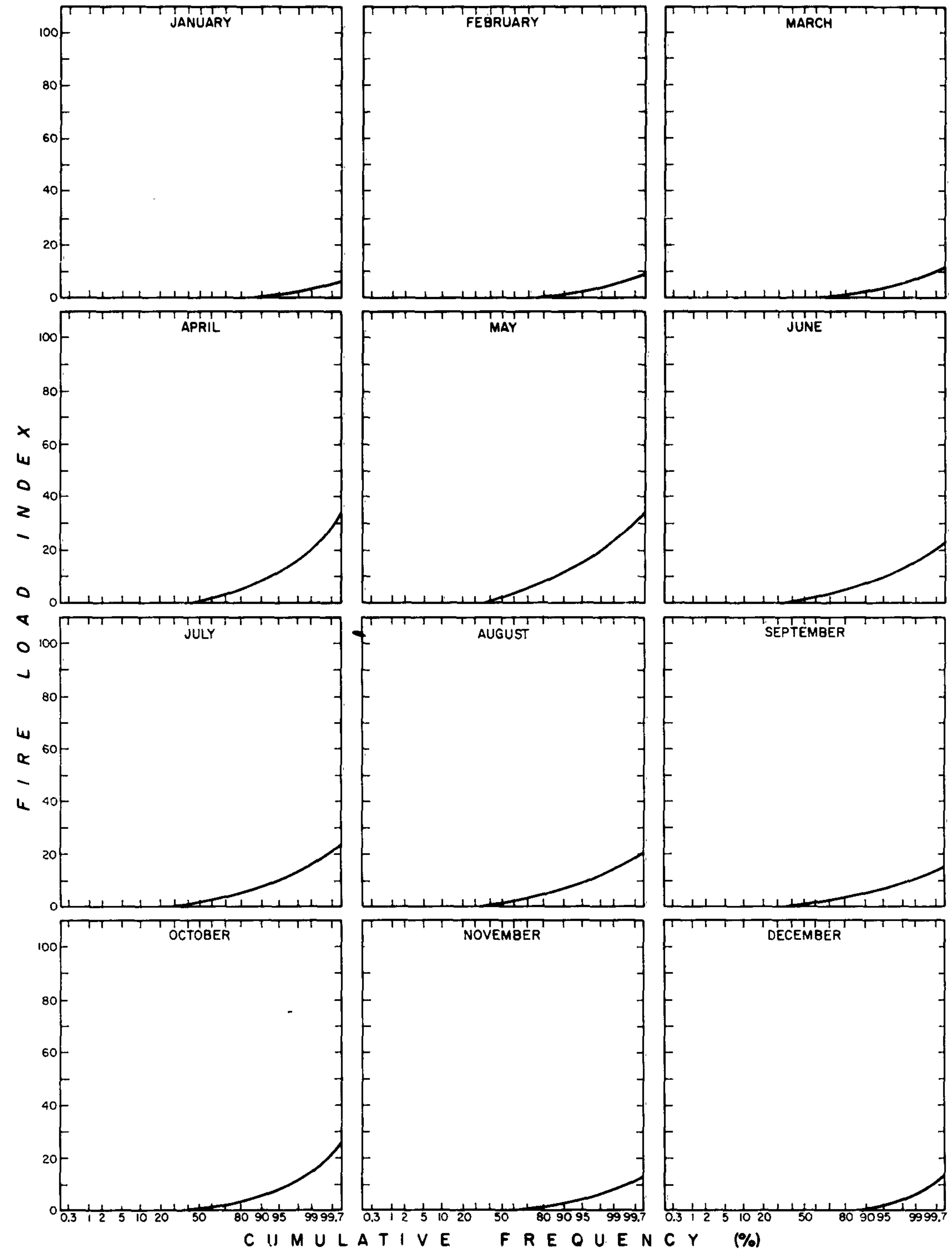
STATION 14771 SYRACUSE, NEW YORK



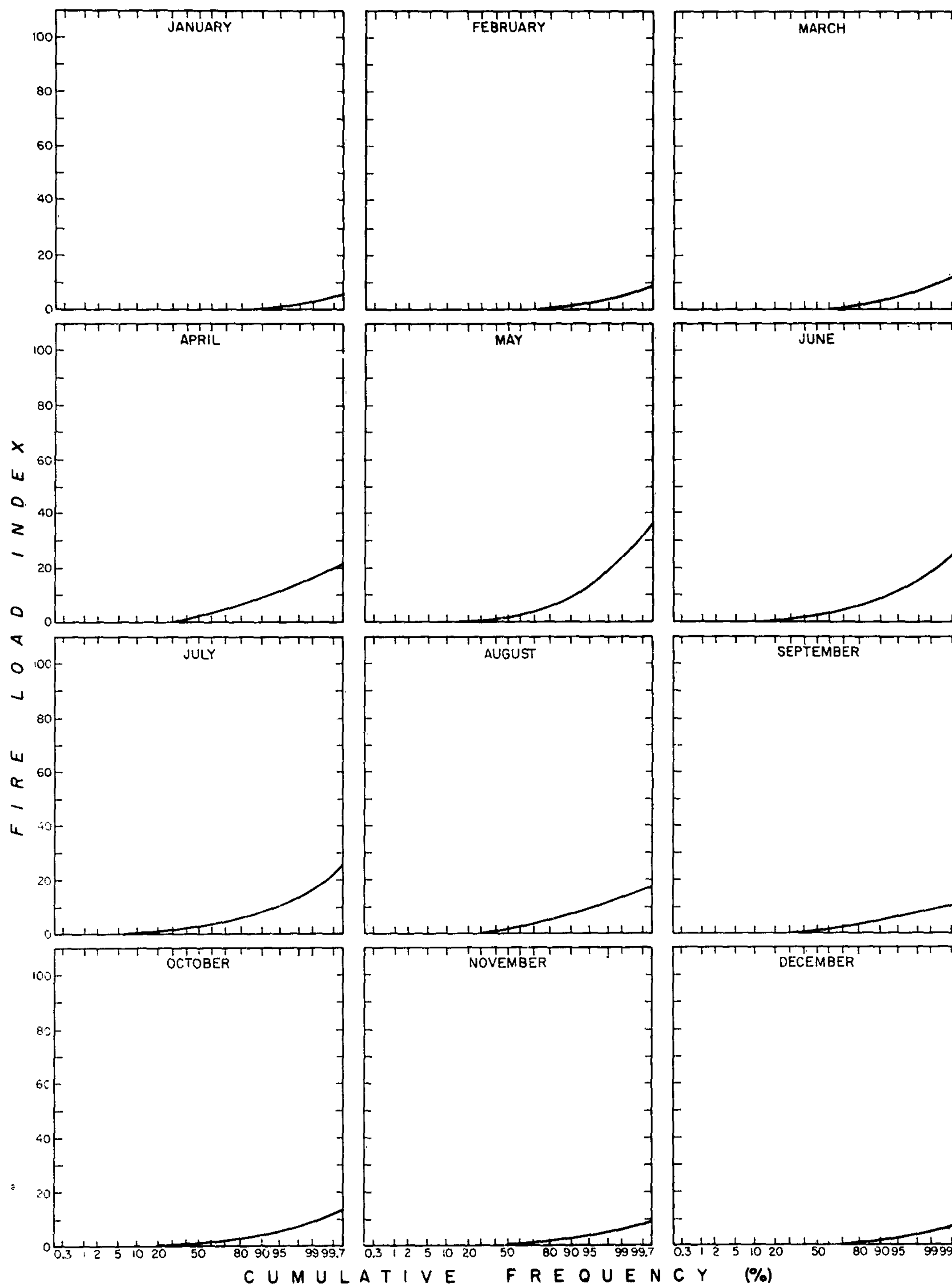
STATION 14735 ALBANY, NEW YORK



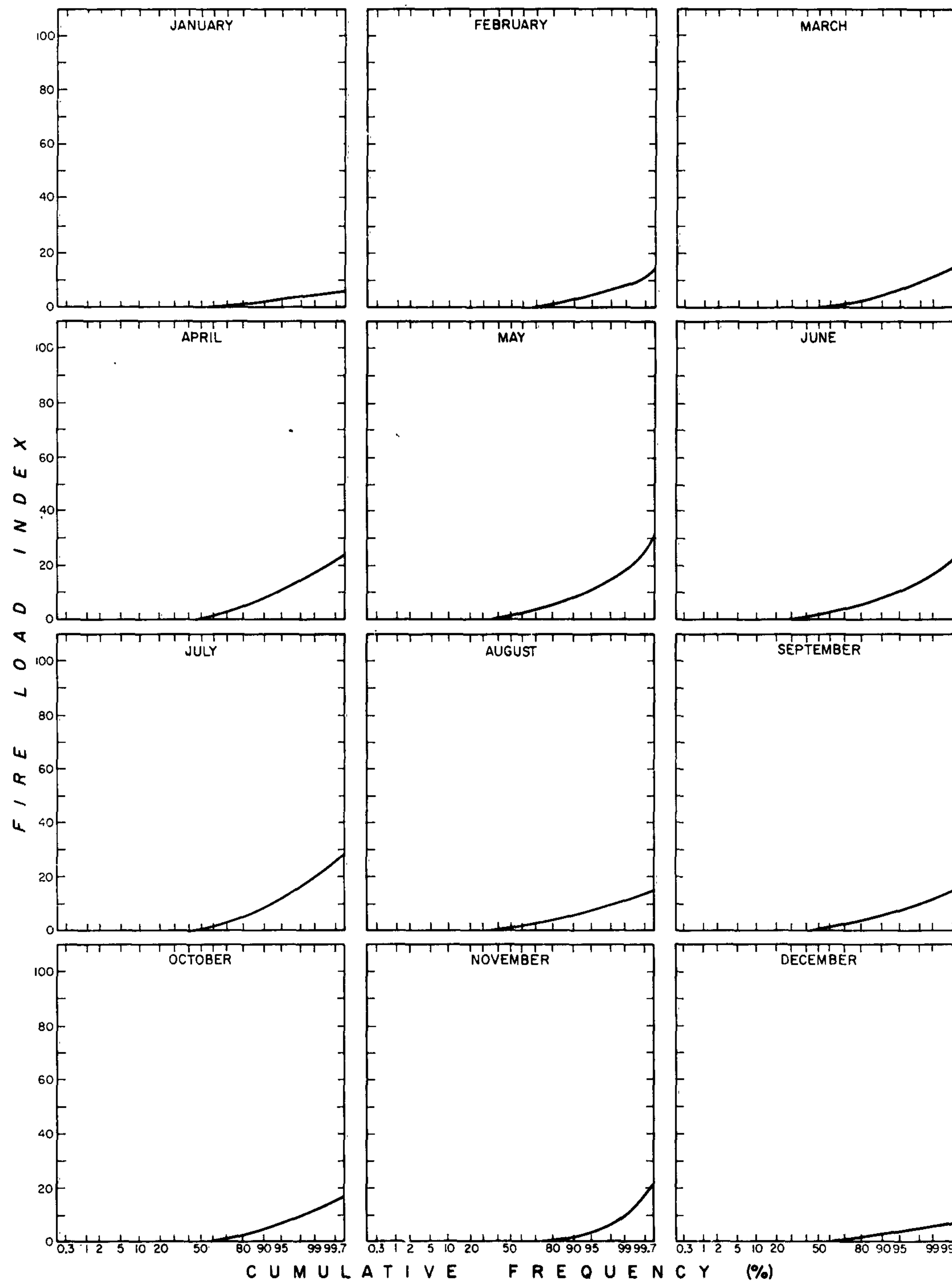
STATION 14740 HARTFORD, CONNECTICUT



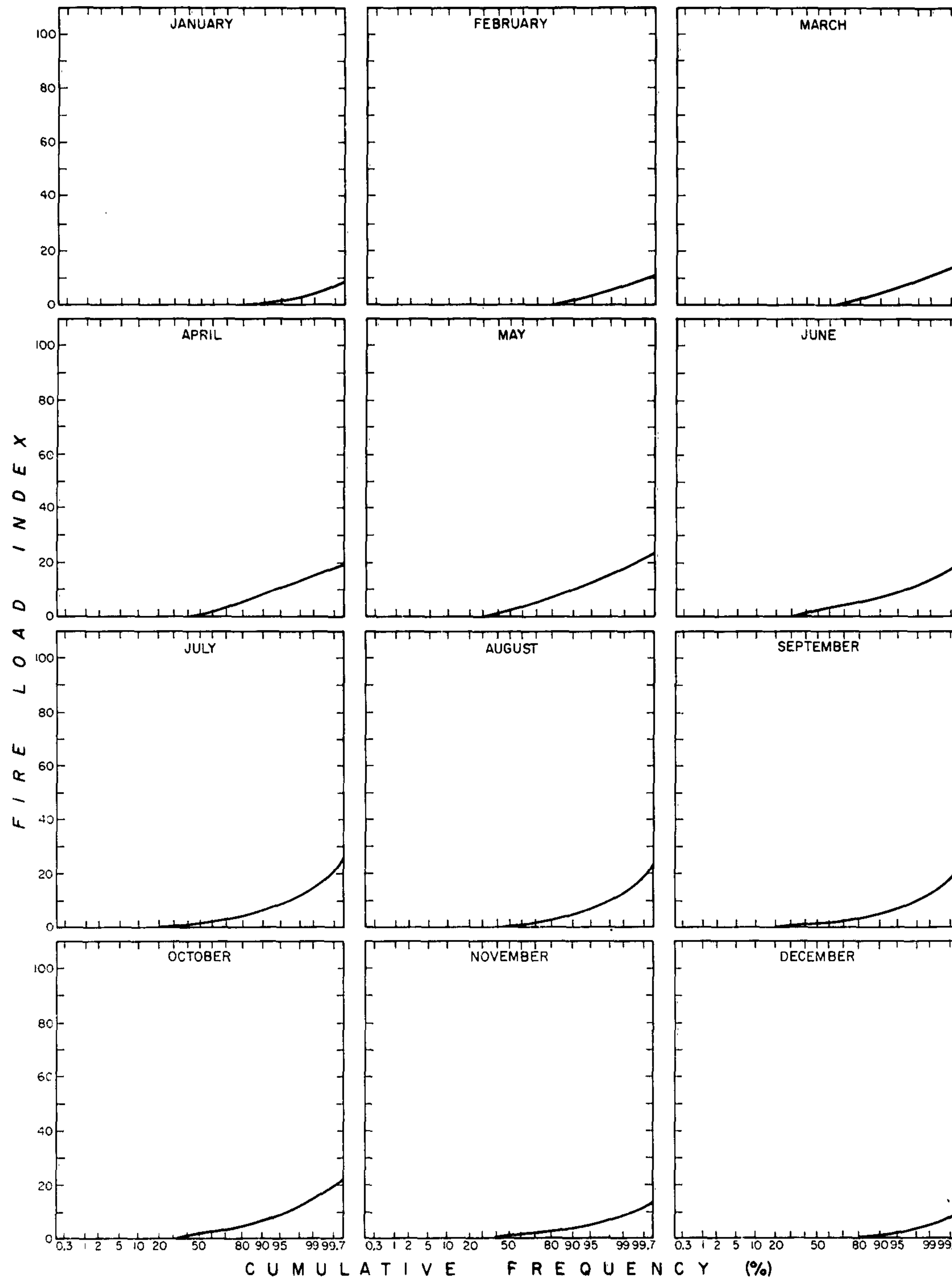
STATION 14778 WILLIAMSPORT, PENNSYLVANIA



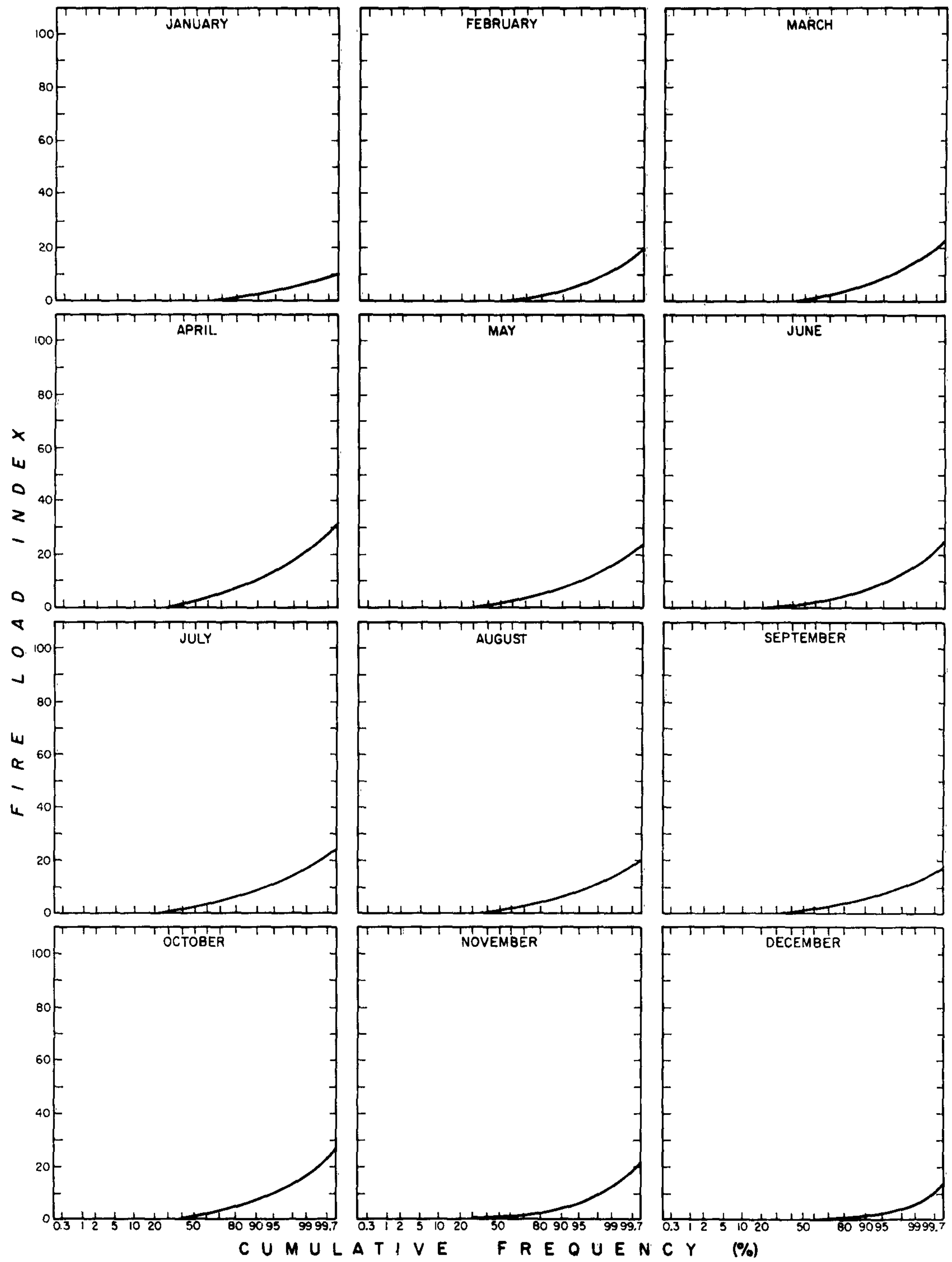
STATION 13739 PHILADELPHIA, PENNSYLVANIA



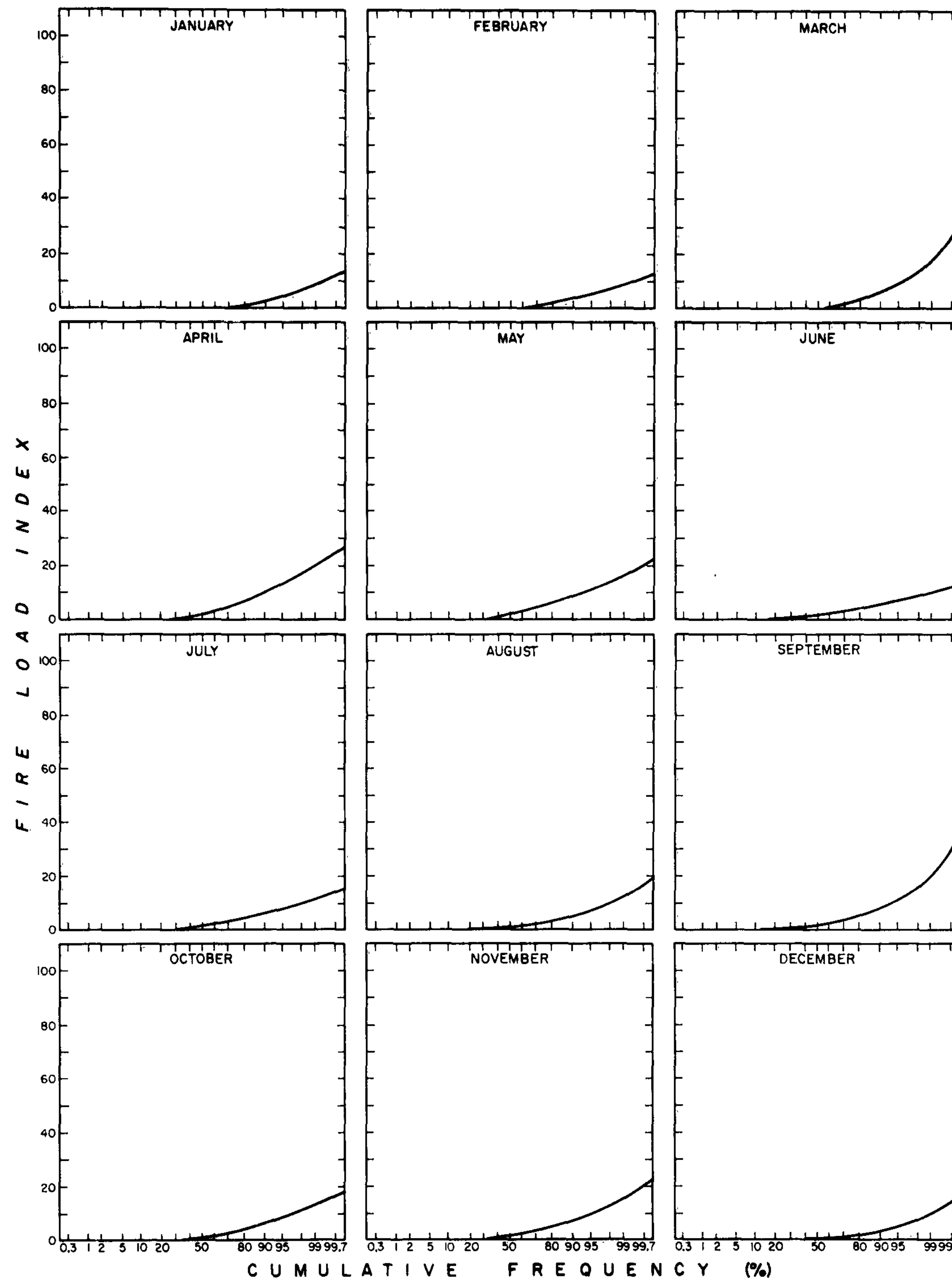
STATION 94823 PITTSBURGH, PENNSYLVANIA



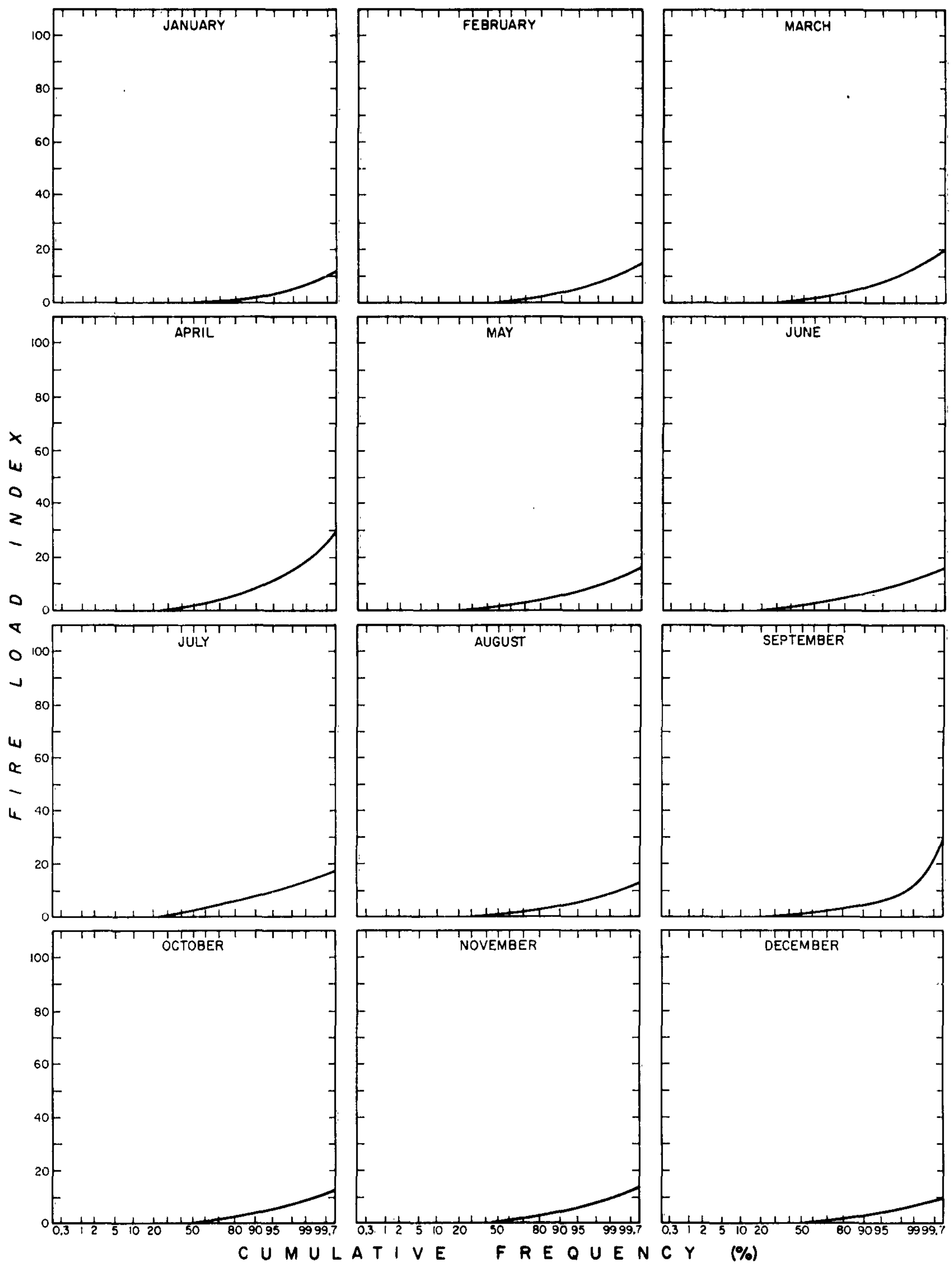
STATION 13743 WASHINGTON, D.C.



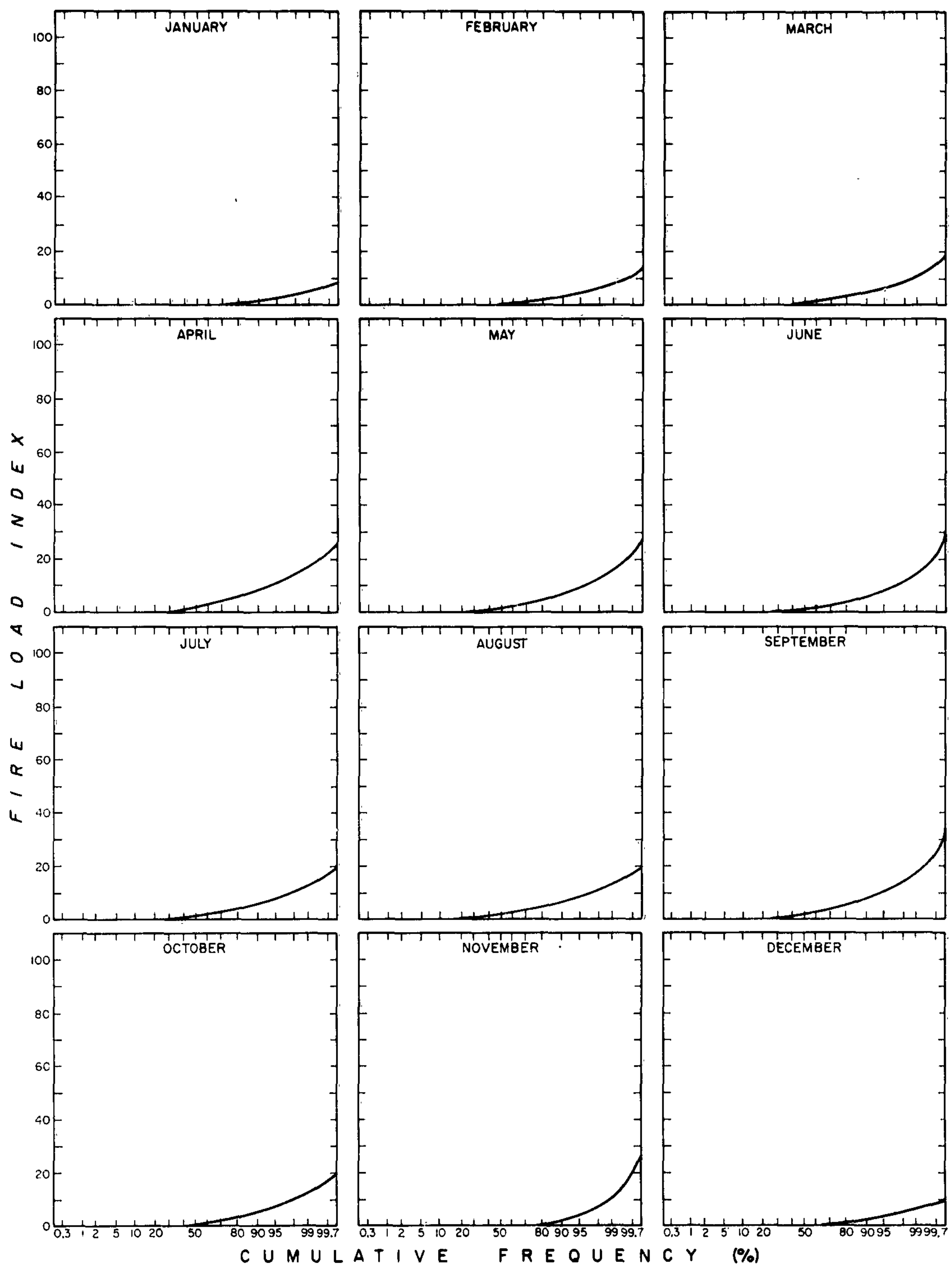
STATION 13866 CHARLESTON, WEST VIRGINIA



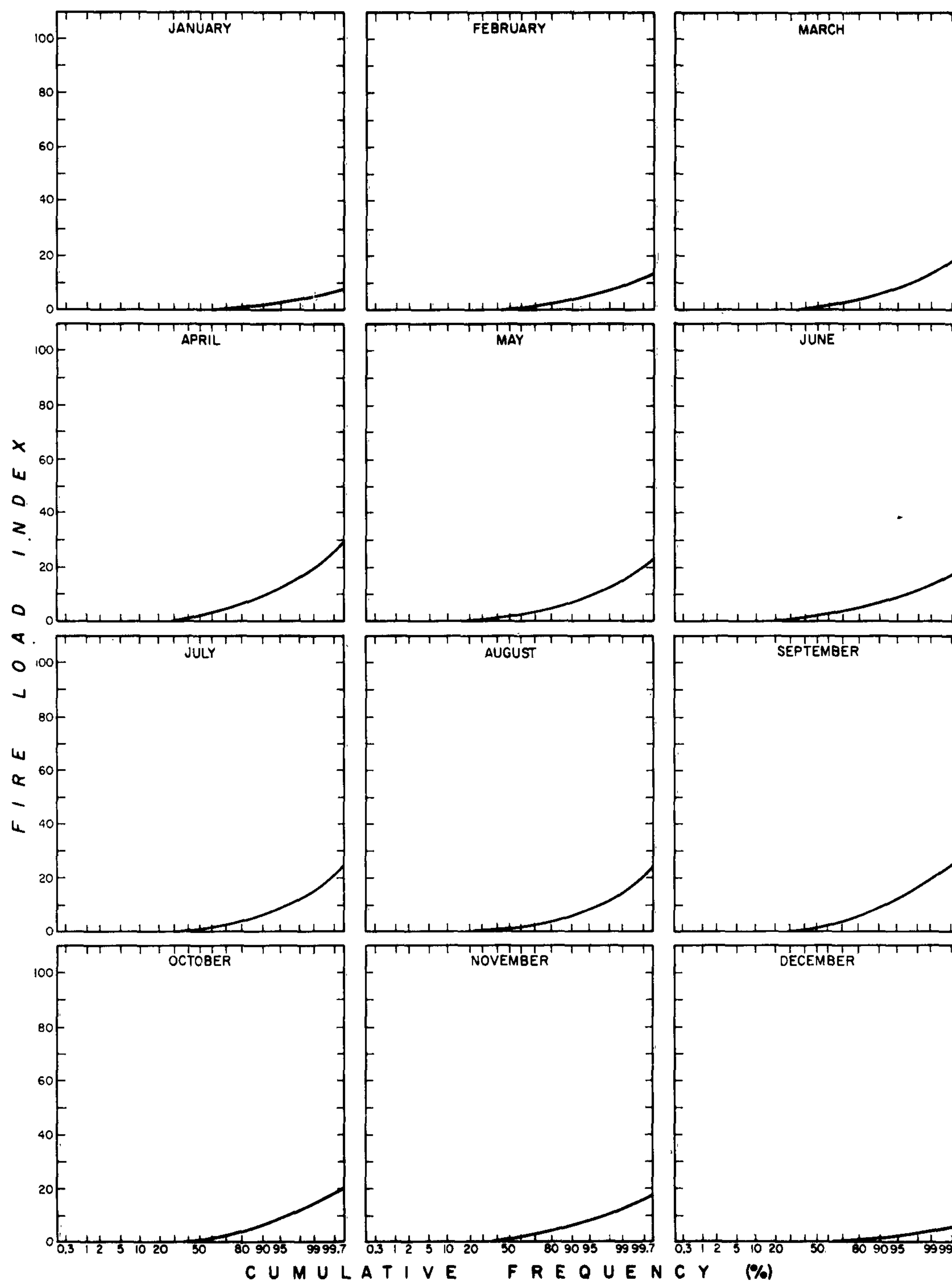
STATION 13740 RICHMOND, VIRGINIA



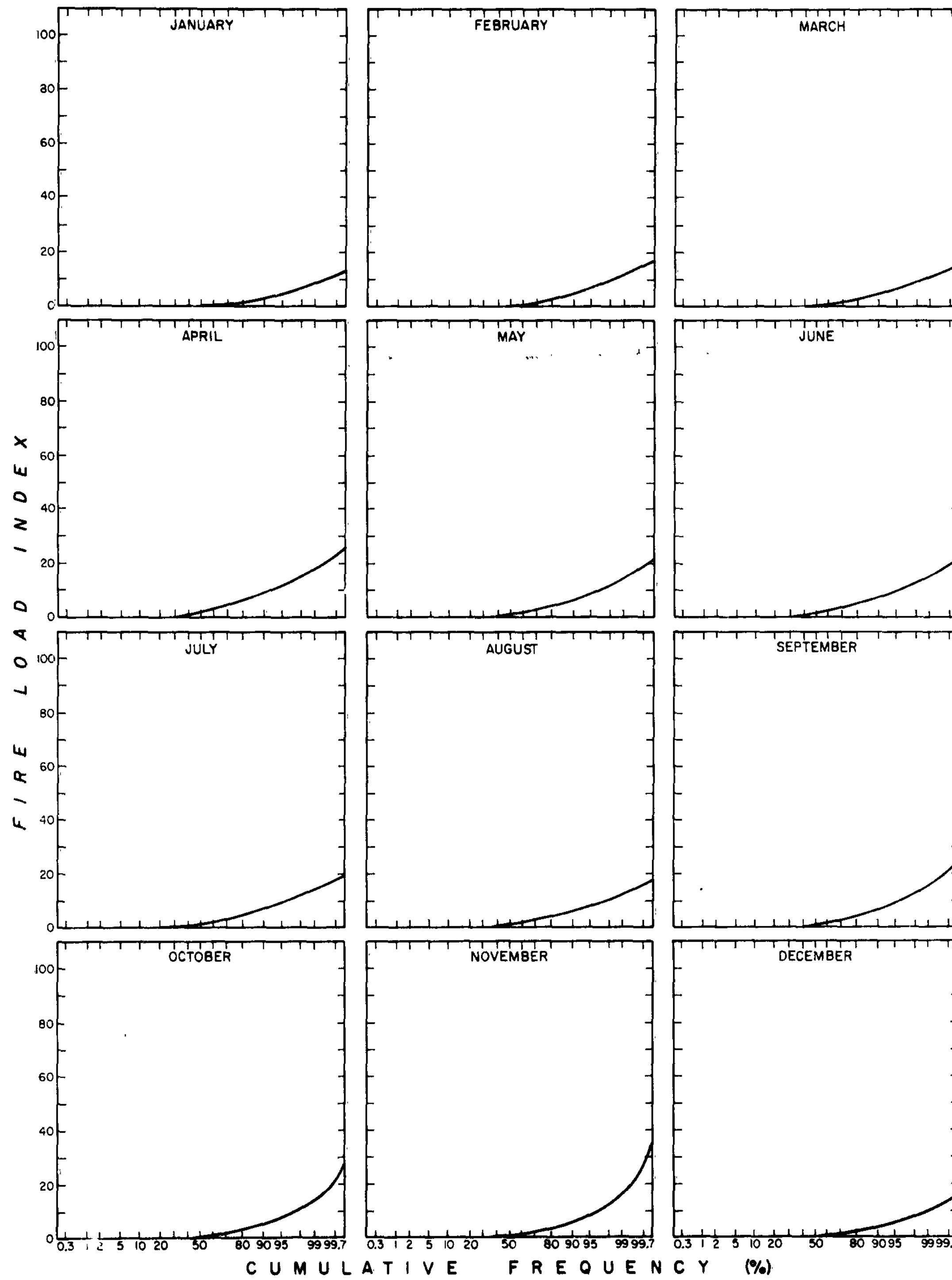
STATION 13891 KNOXVILLE, TENNESSEE



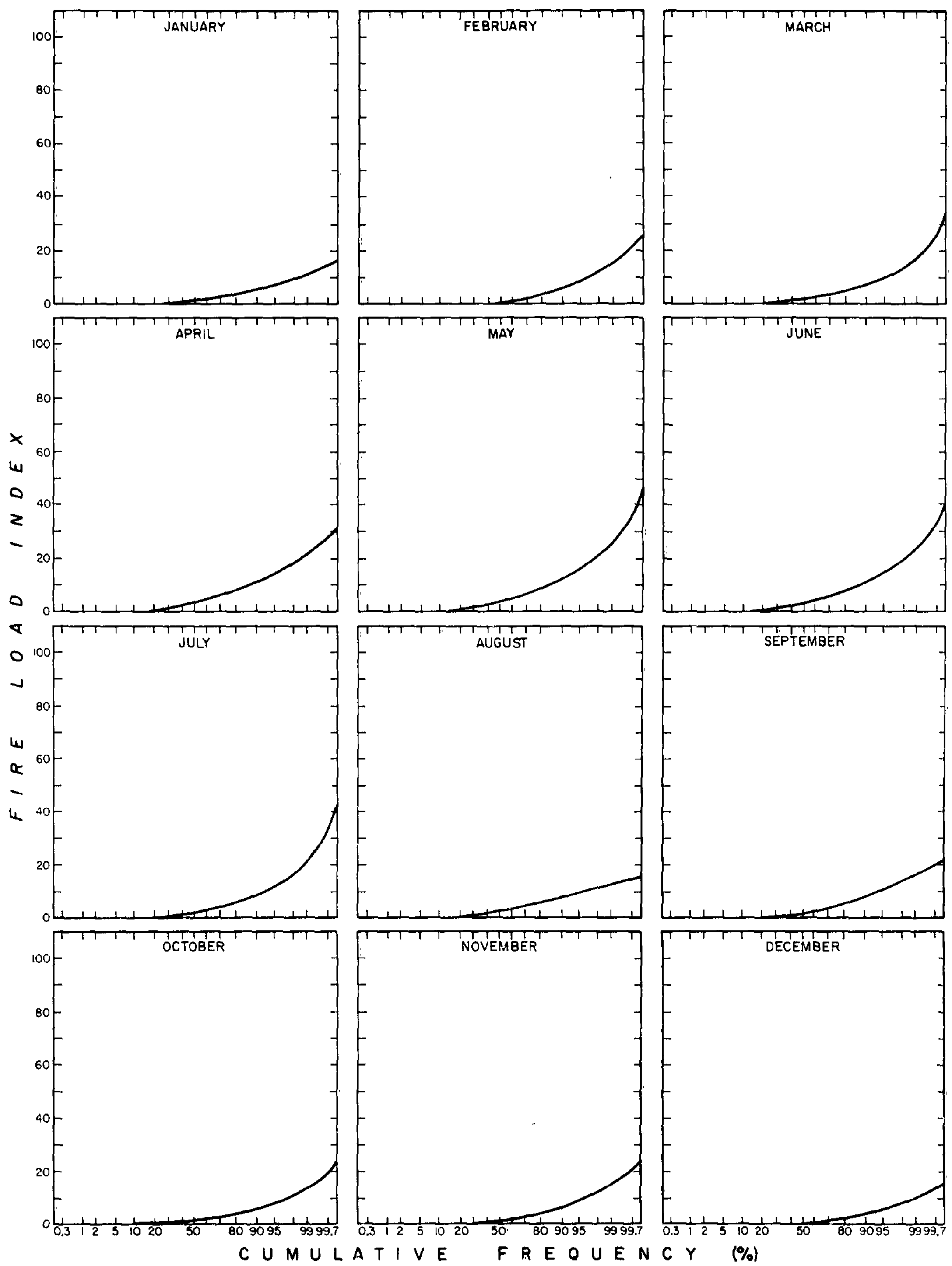
STATION 13882 CHATTANOOGA, TENNESSEE



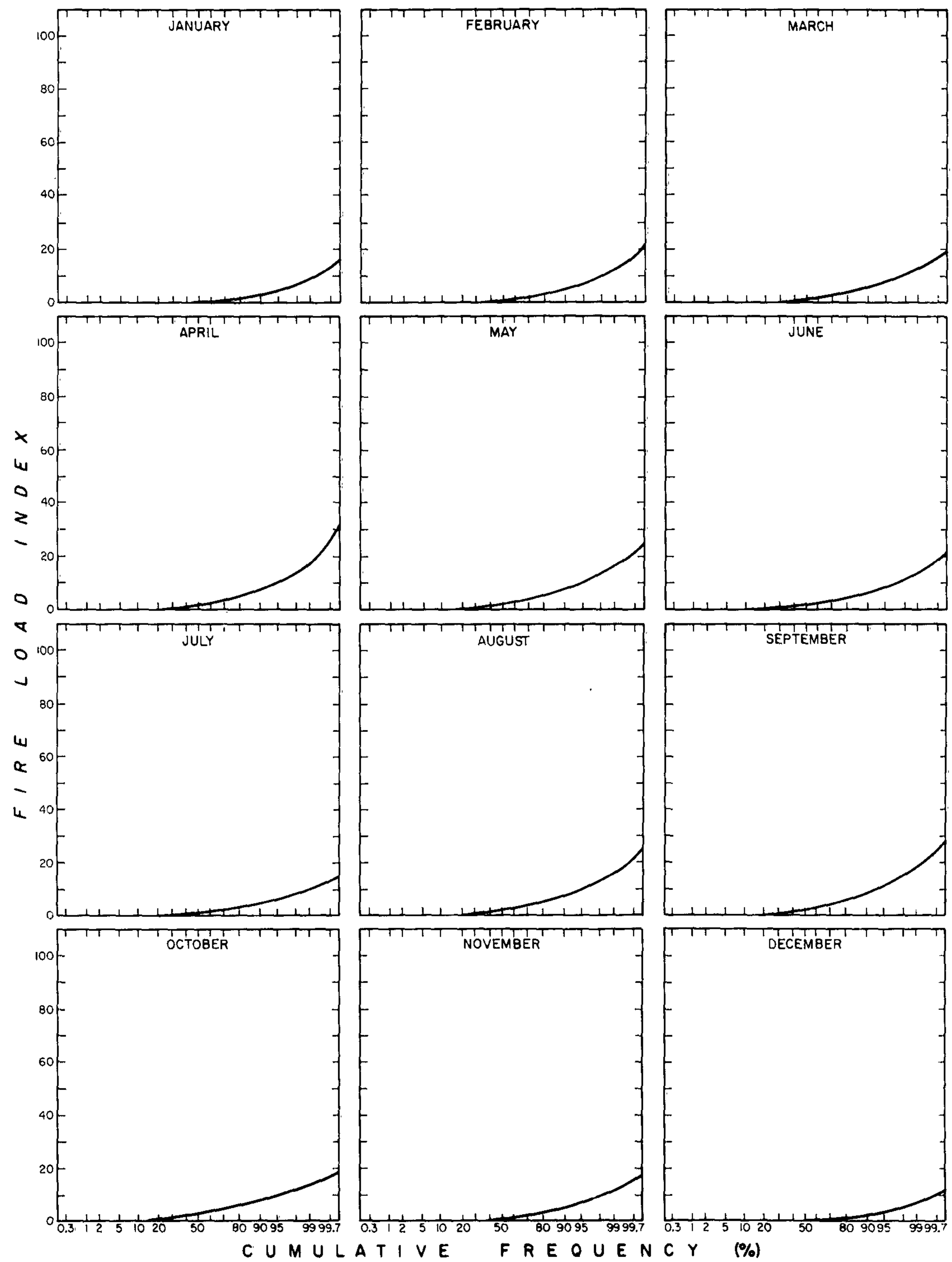
STATION 13722 RALEIGH, NORTH CAROLINA



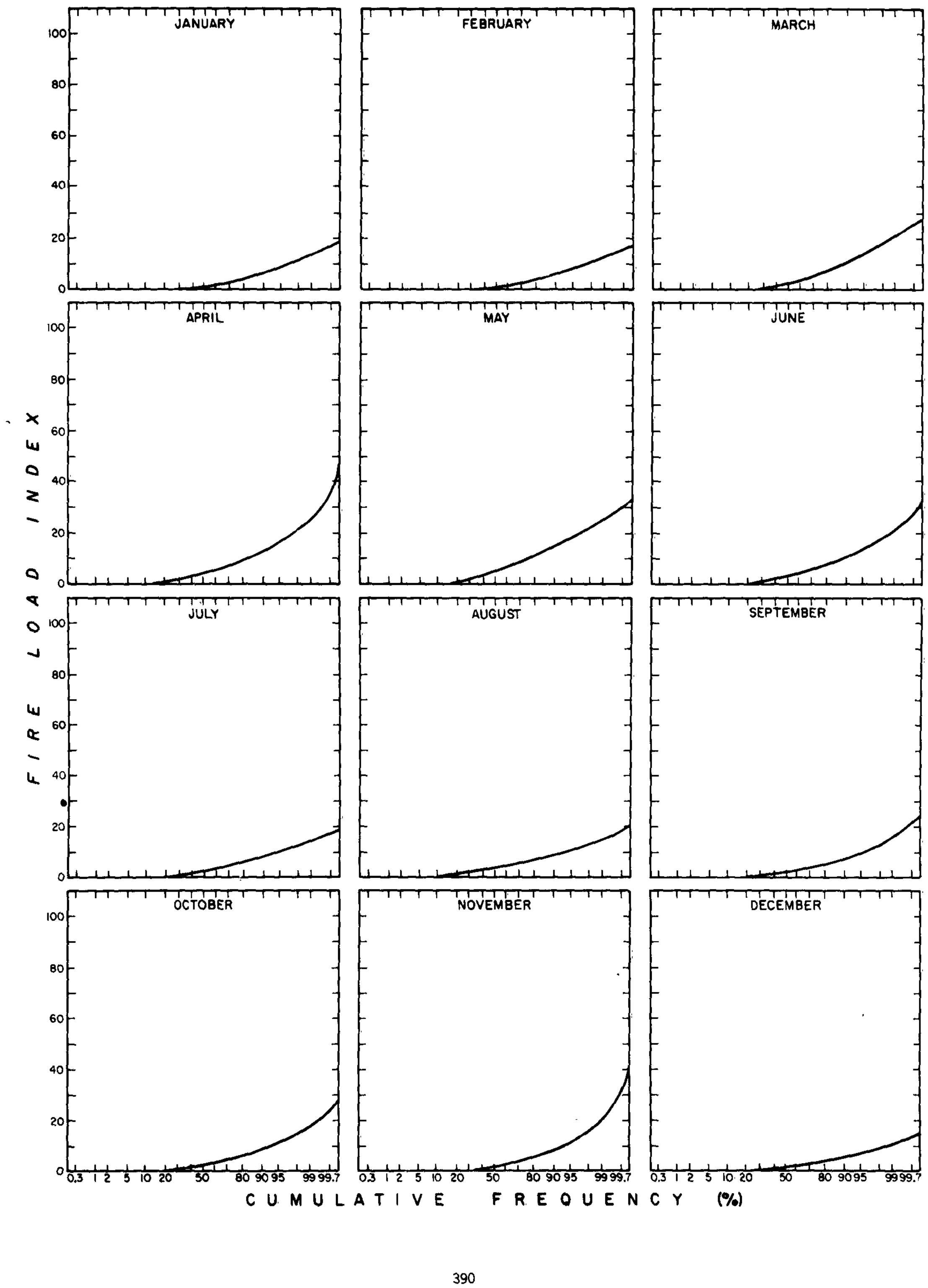
STATION 13883 COLUMBIA, SOUTH CAROLINA



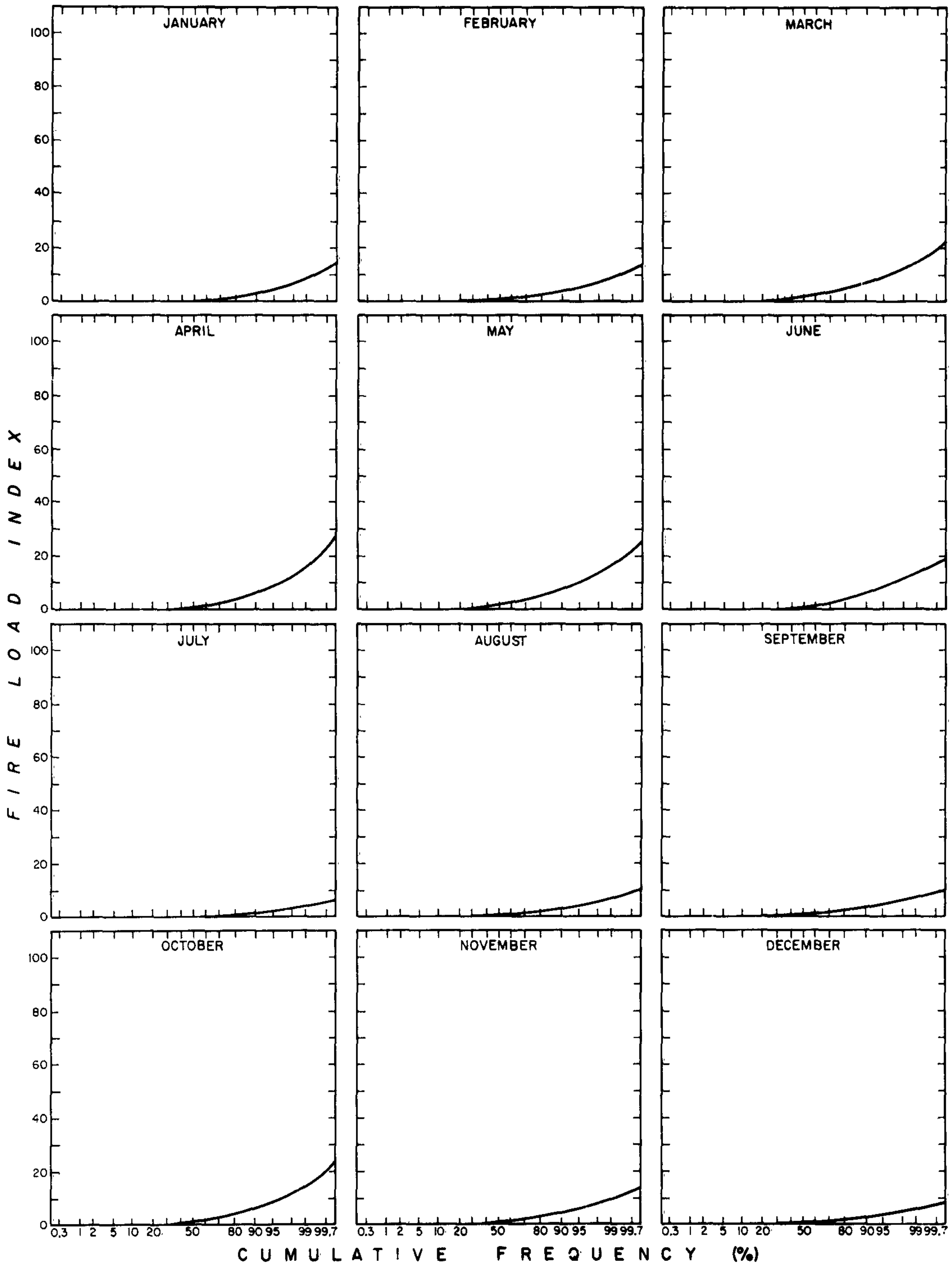
STATION 13895 MONTGOMERY, ALABAMA



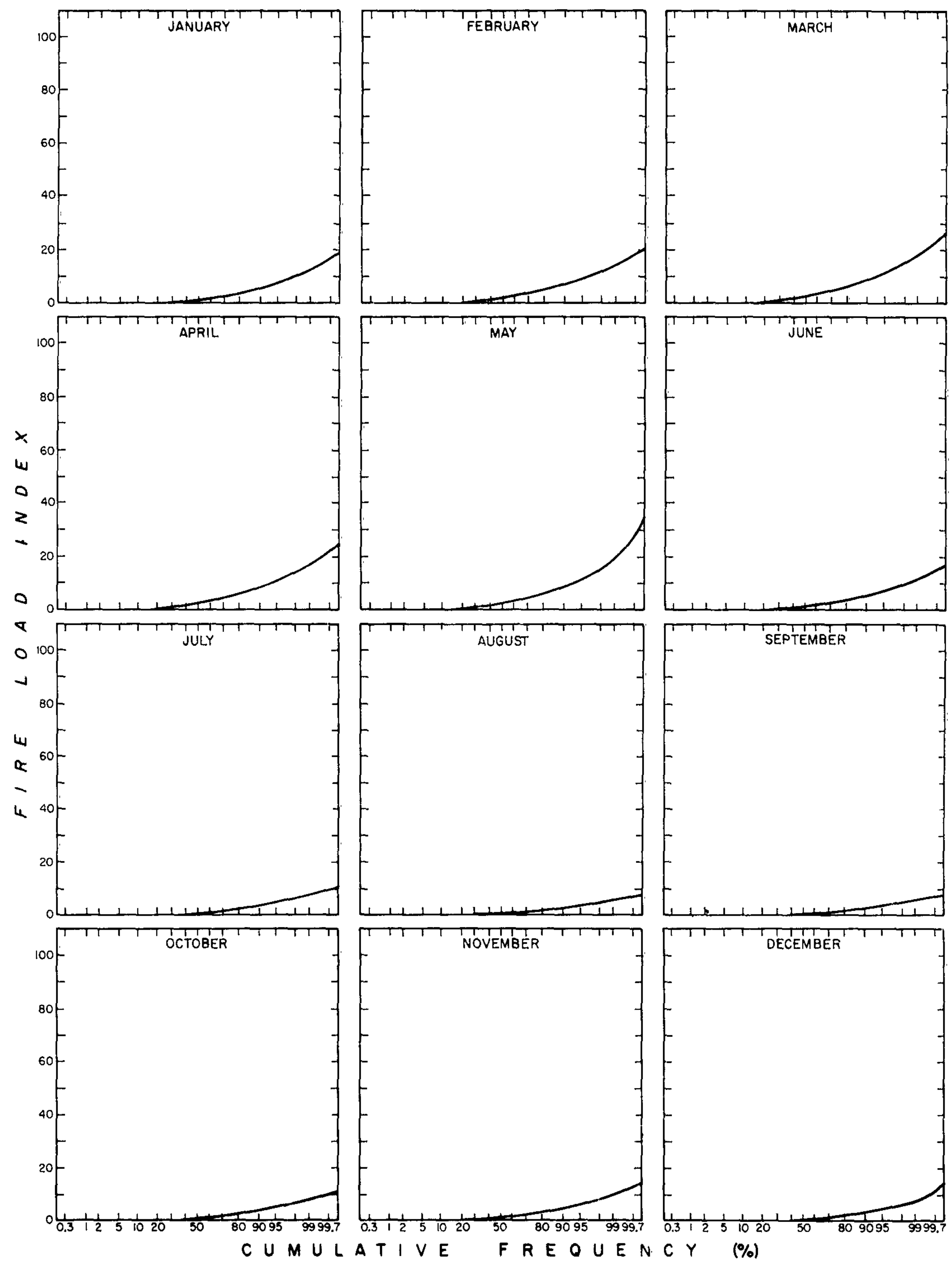
STATION 3813 MACON, GEORGIA



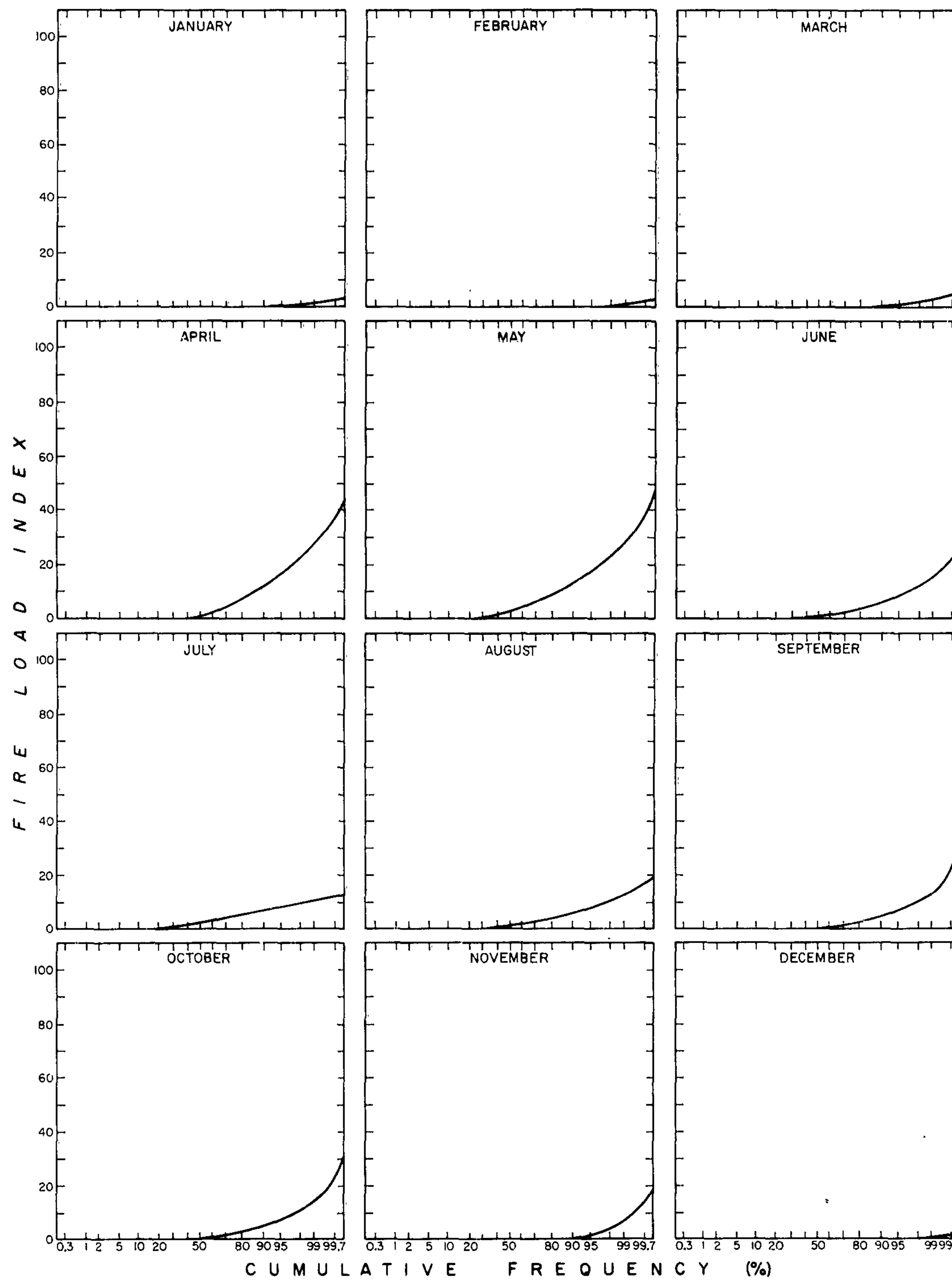
STATION 93805 TALLAHASSEE, FLORIDA



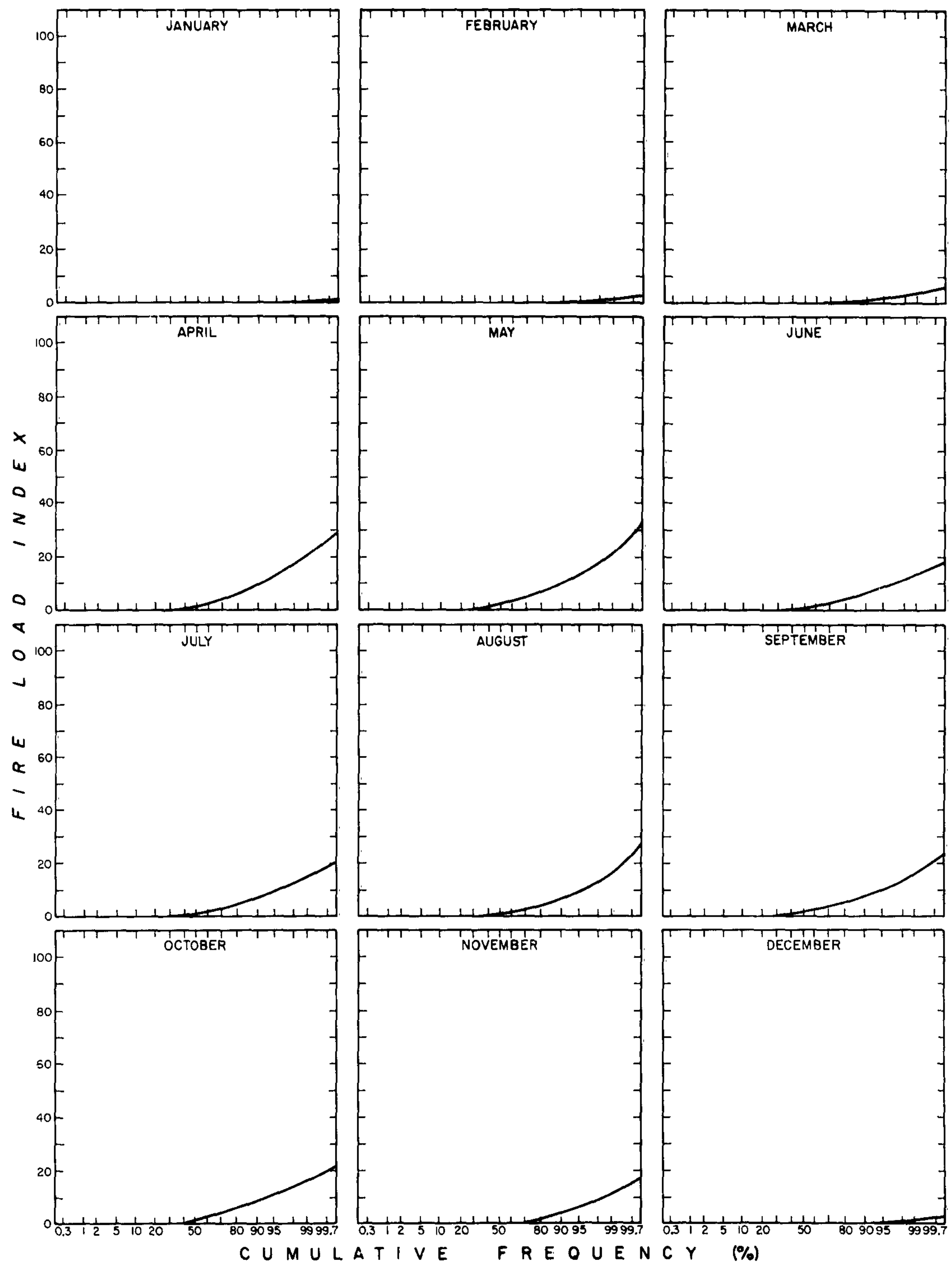
STATION 12841 ORLANDO, FLORIDA



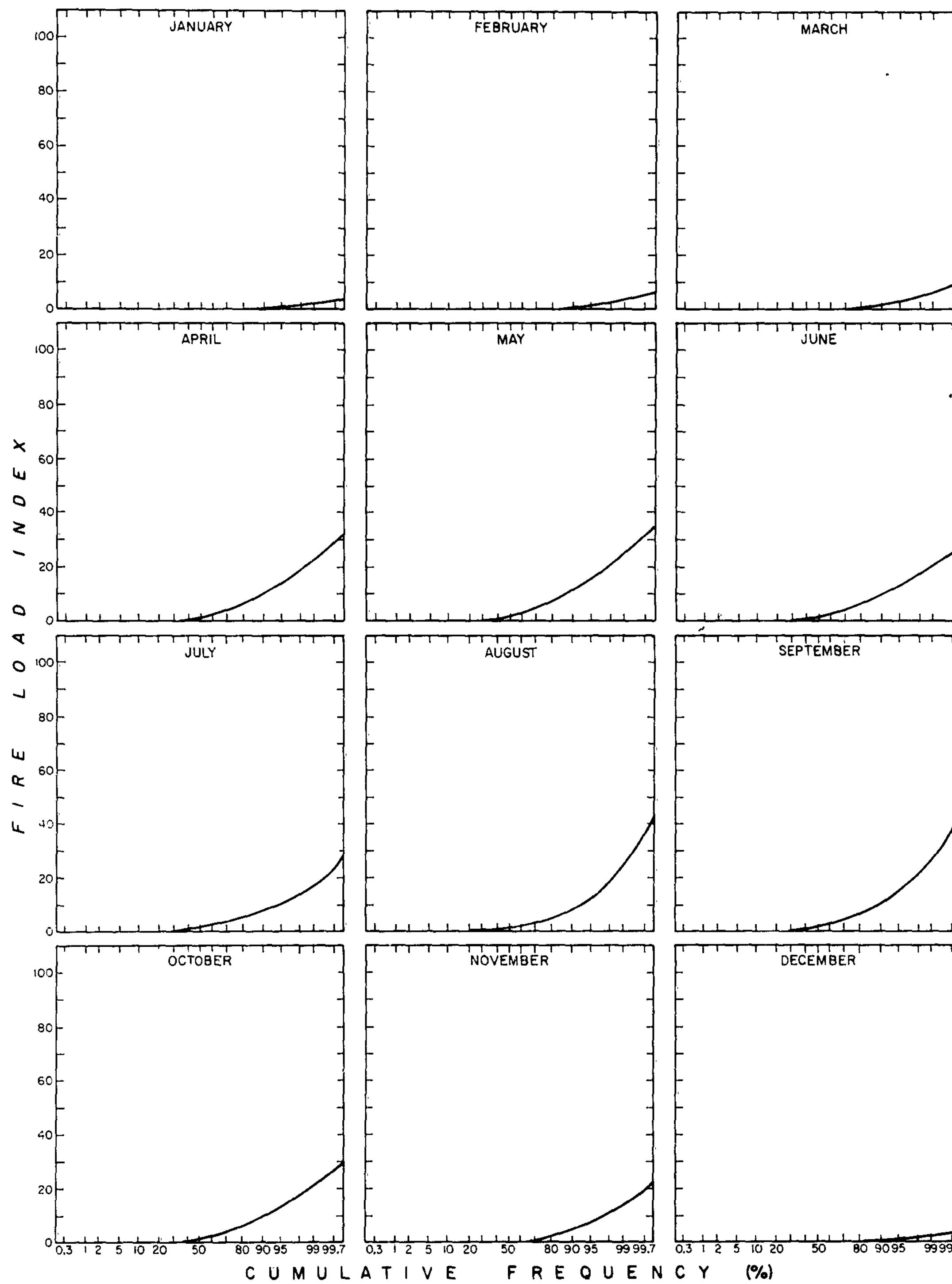
STATION 14918 INTERNATIONAL FALLS, MINNESOTA



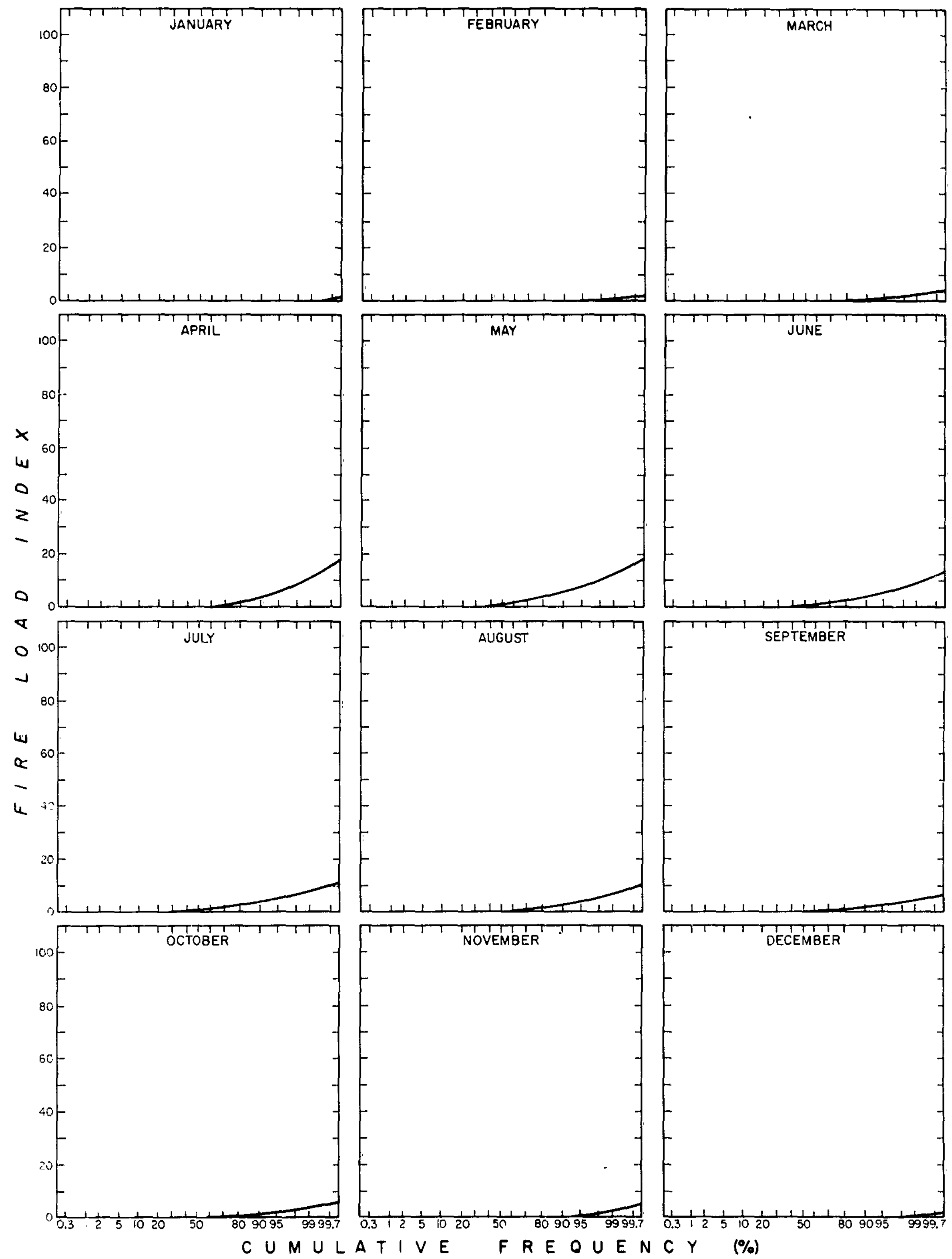
STATION 14991 EAU CLAIRE, WISCONSIN



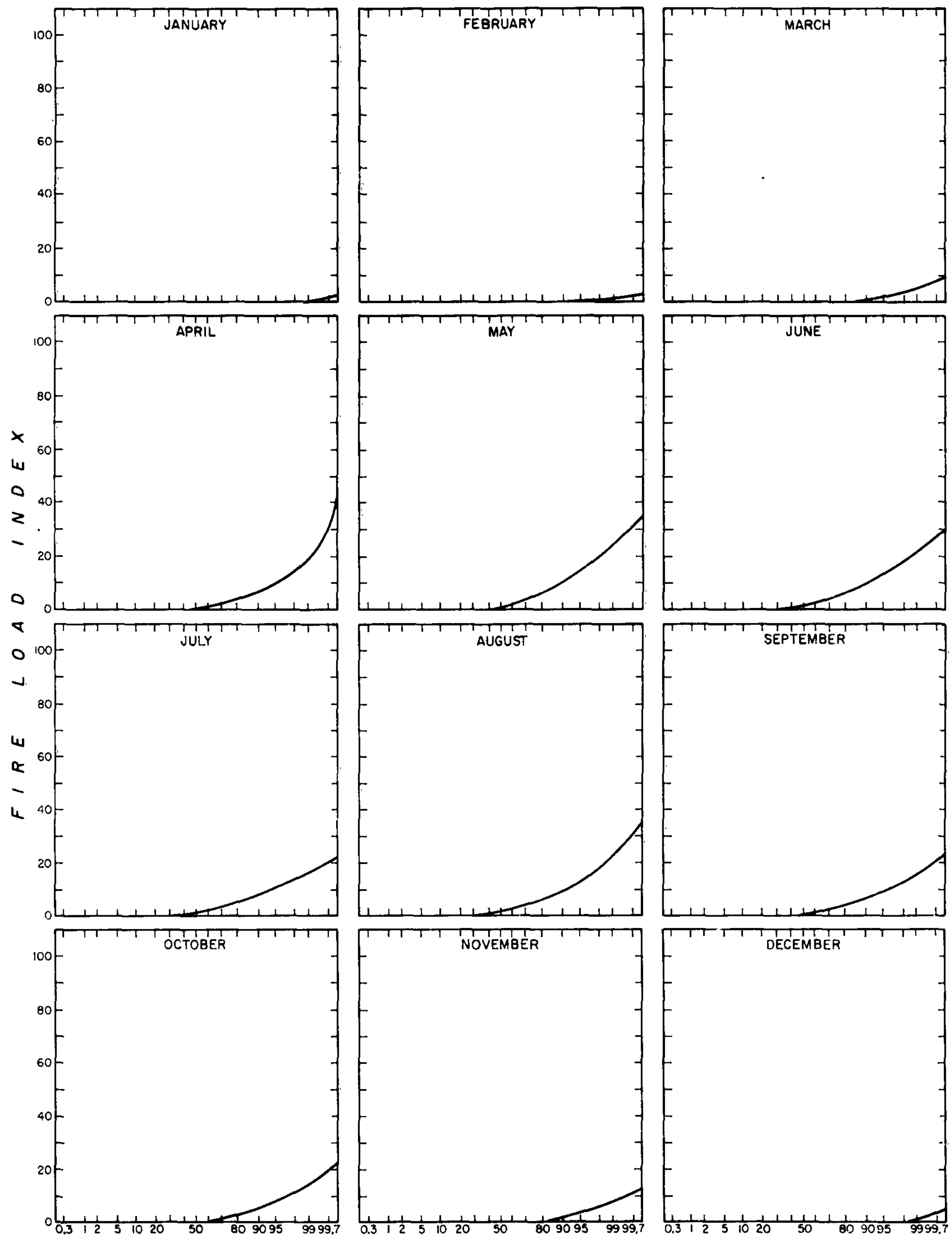
STATION 14837 MADISON, WISCONSIN



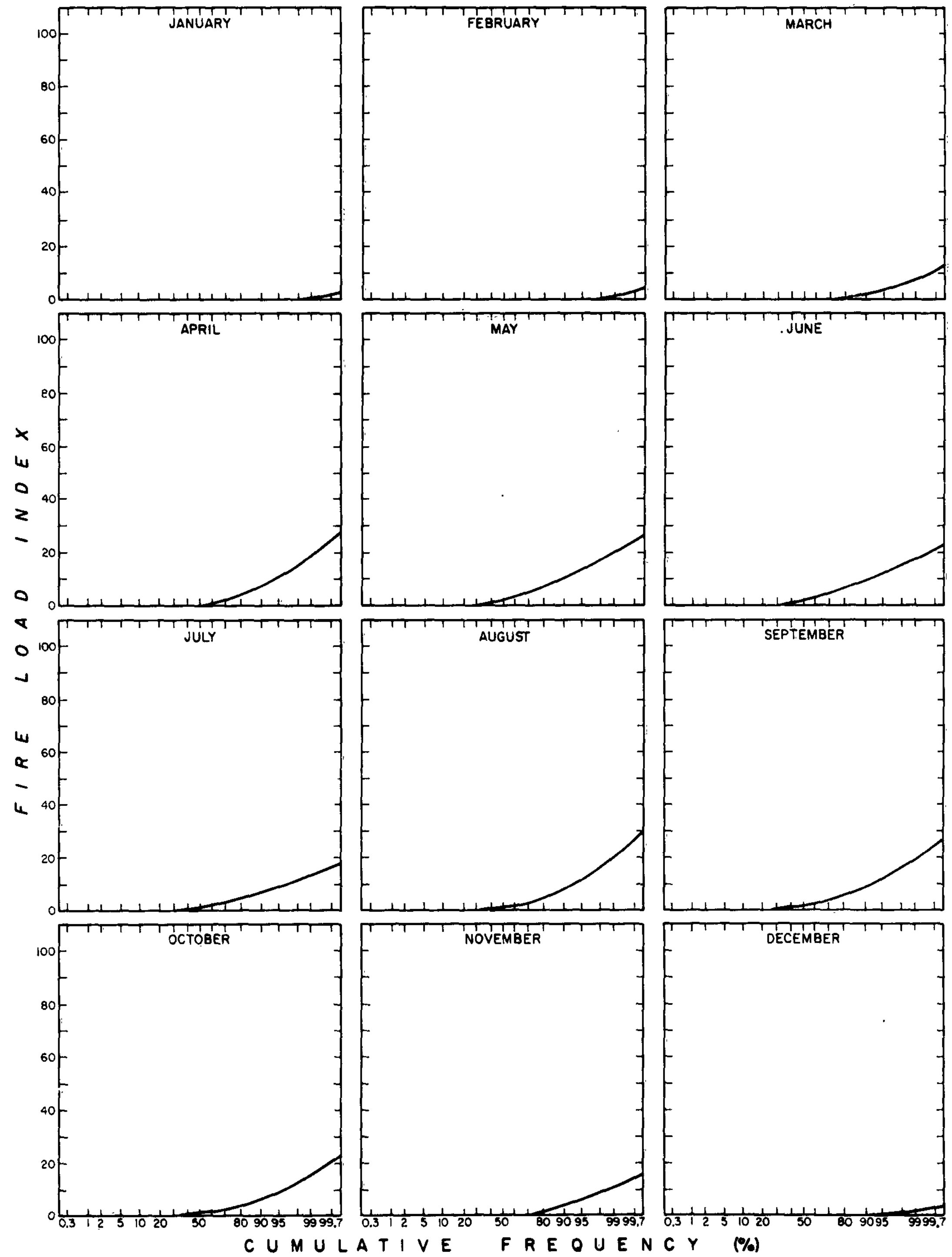
STATION 14847 SAULT STE. MARIE, MICHIGAN



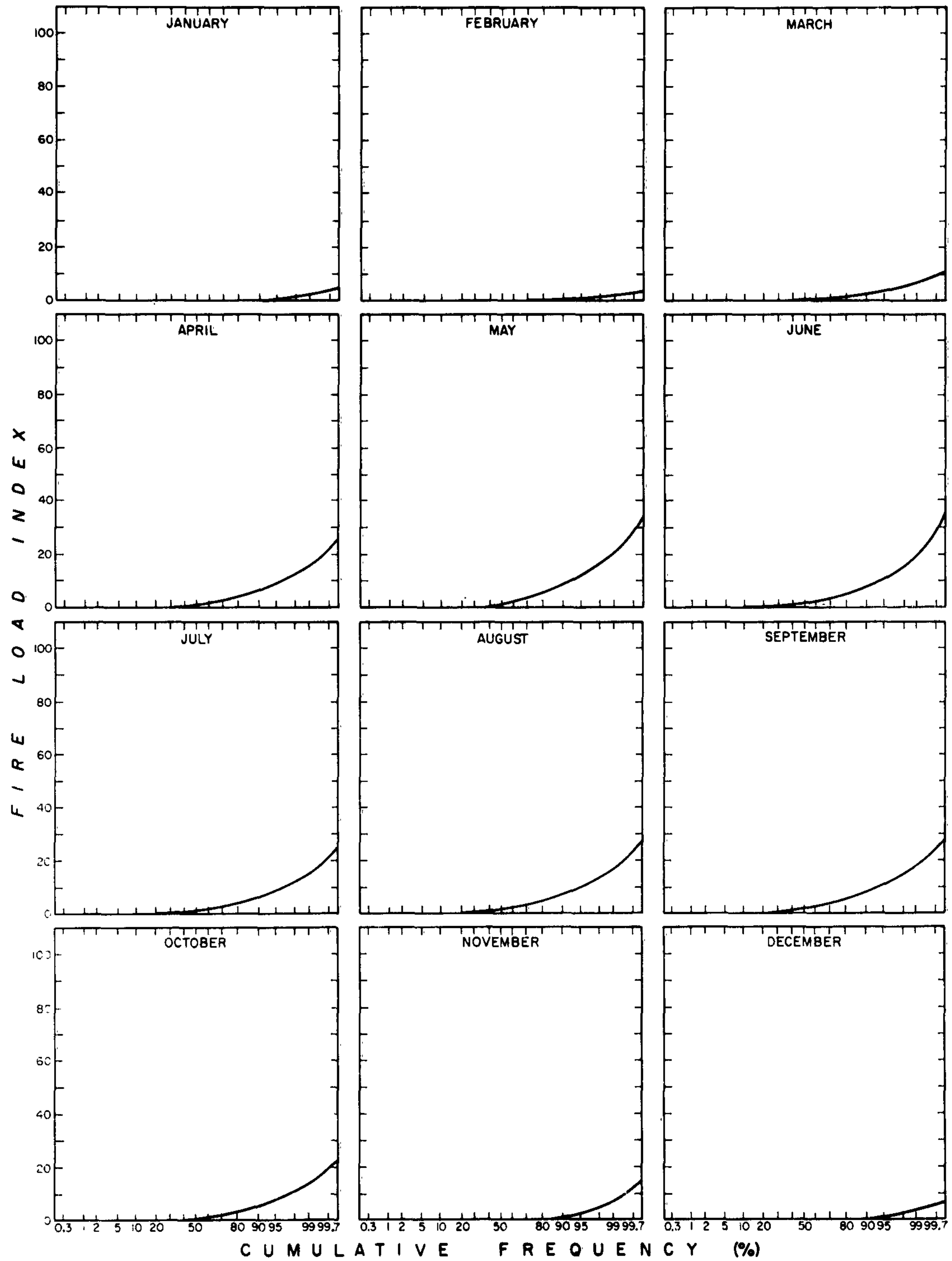
STATION 14850 TRAVERSE CITY, MICHIGAN



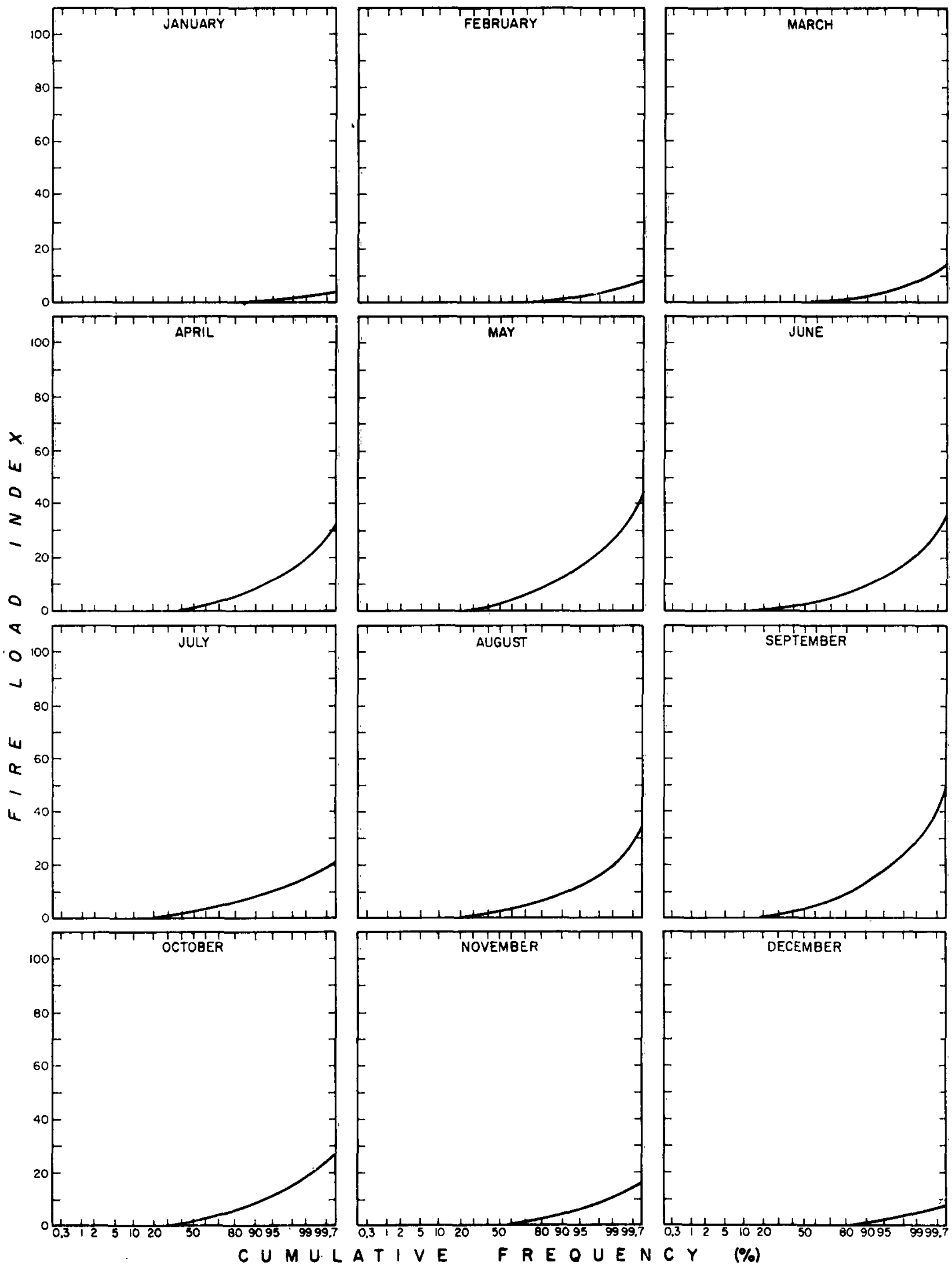
STATION 14830 GRAND RAPIDS, MICHIGAN



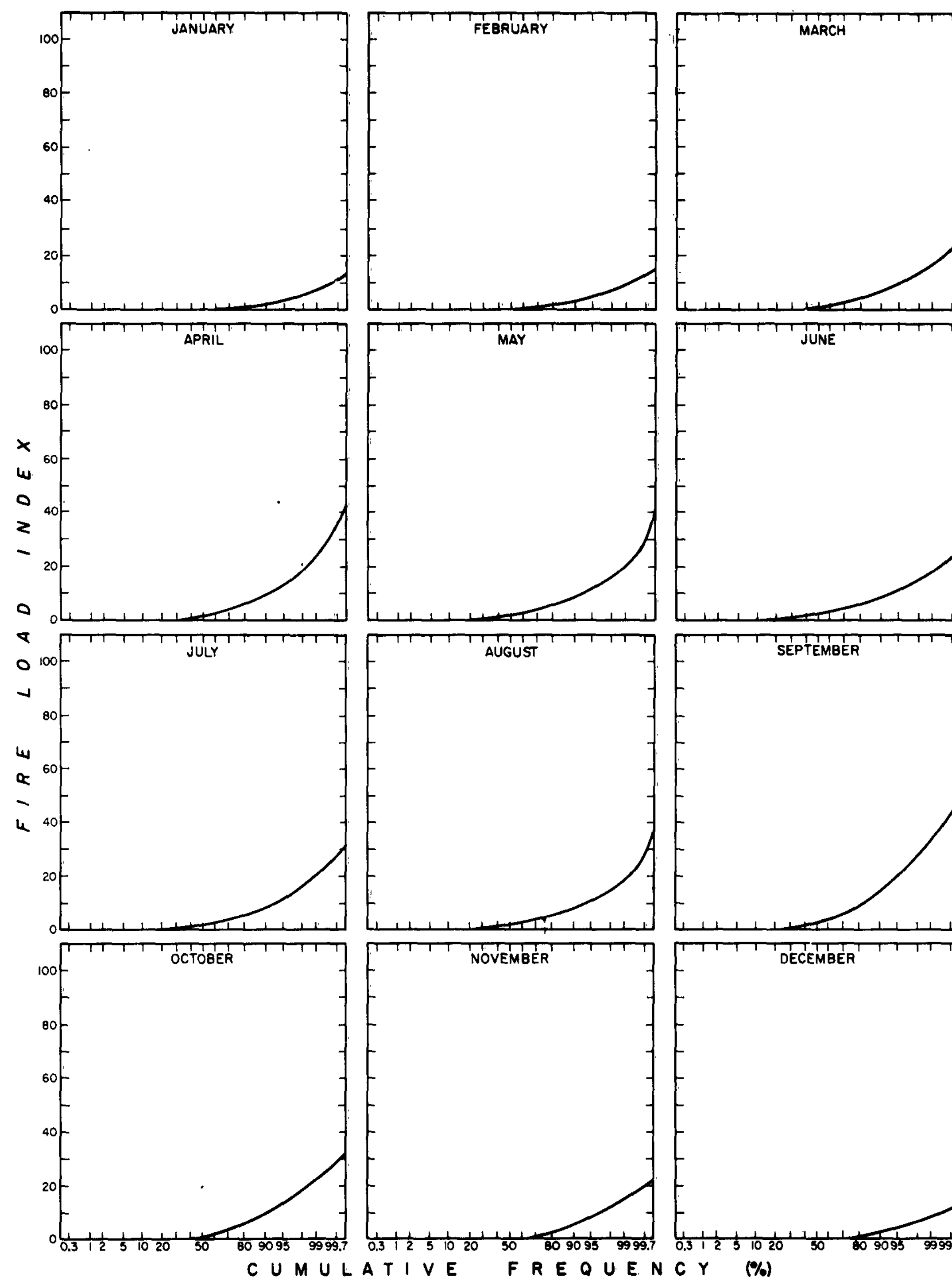
STATION 14822 DETROIT, MICHIGAN



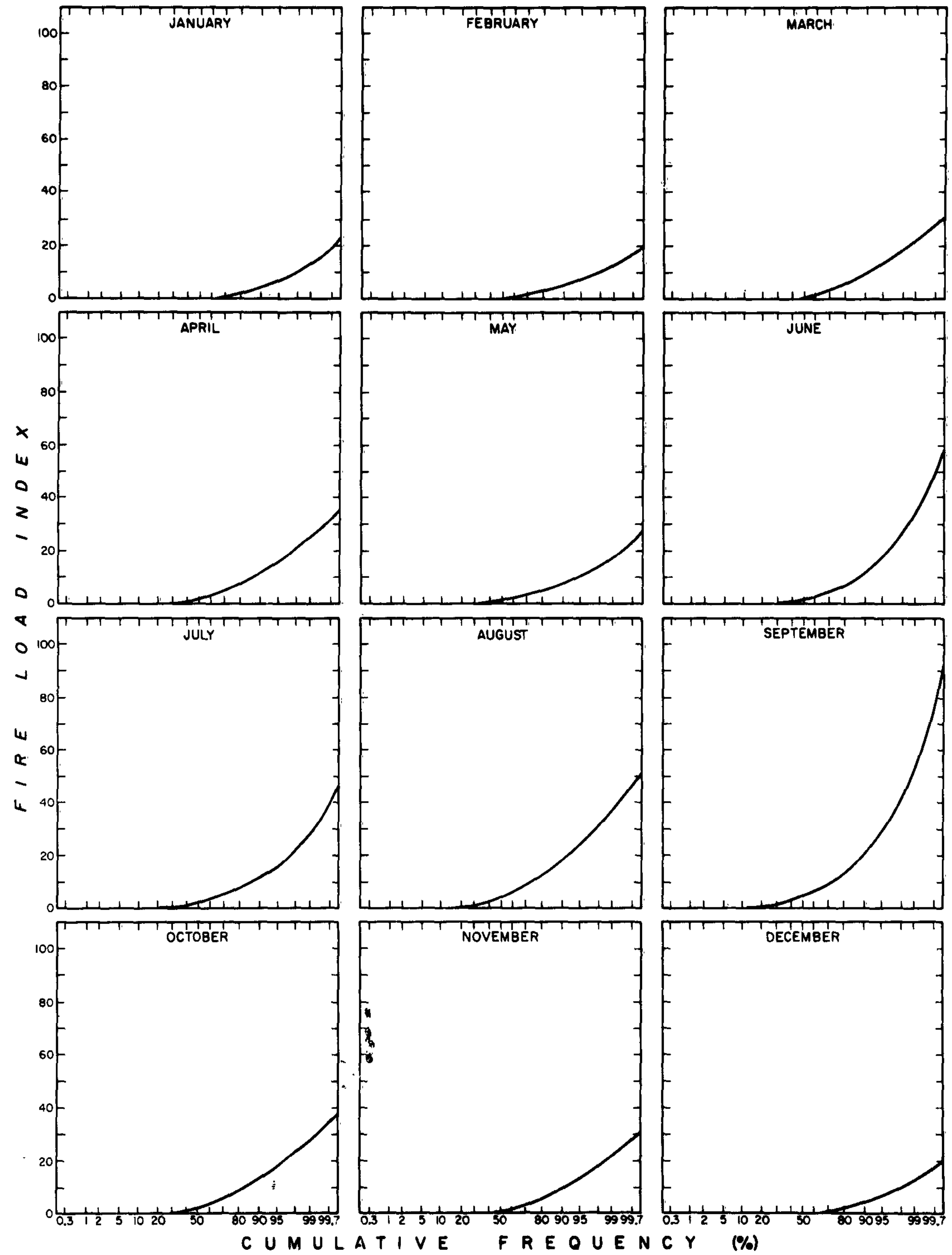
STATION 14819 CHICAGO (MIDWAY), ILLINOIS



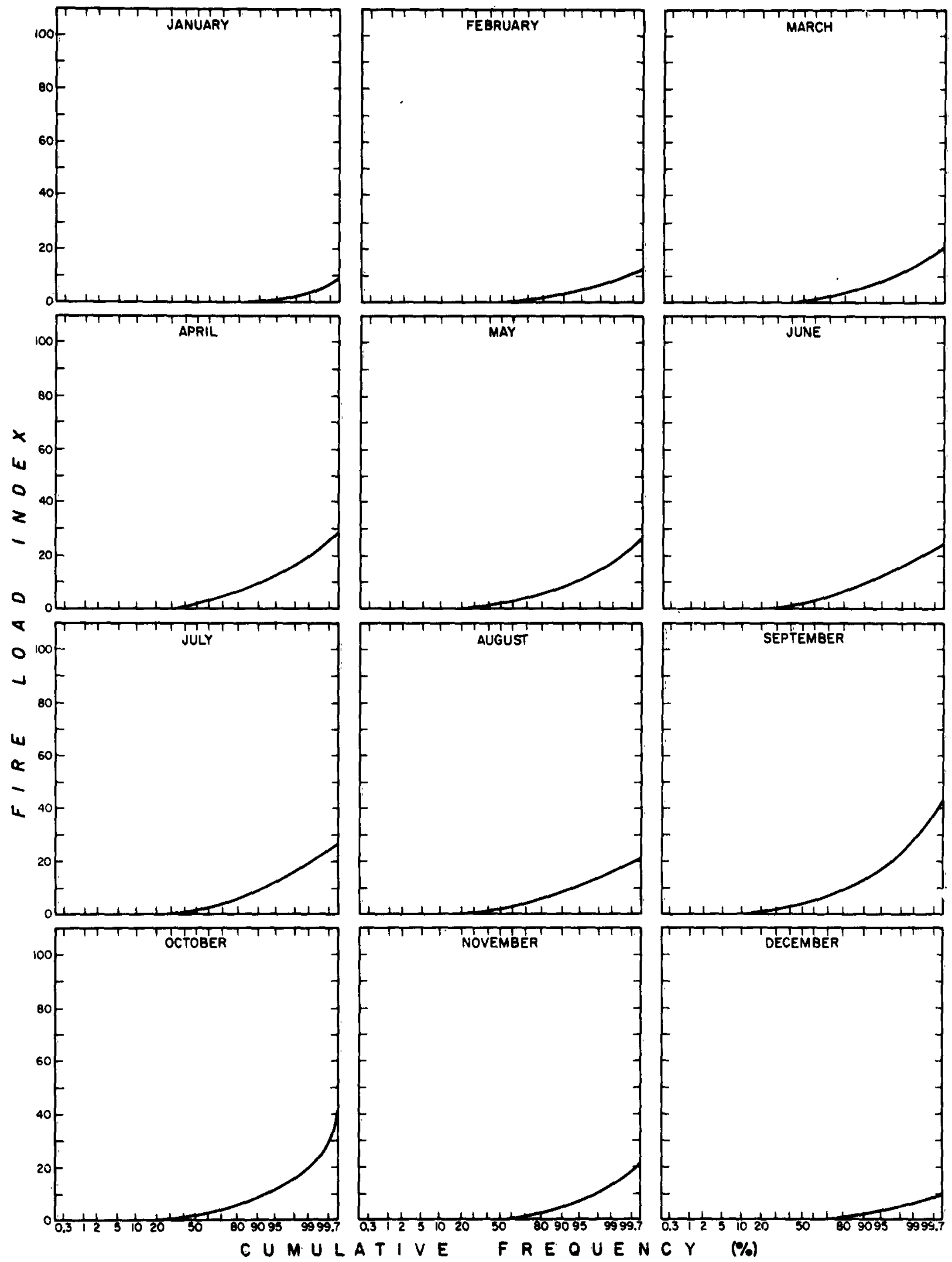
STATION 13994 ST. LOUIS, MISSOURI



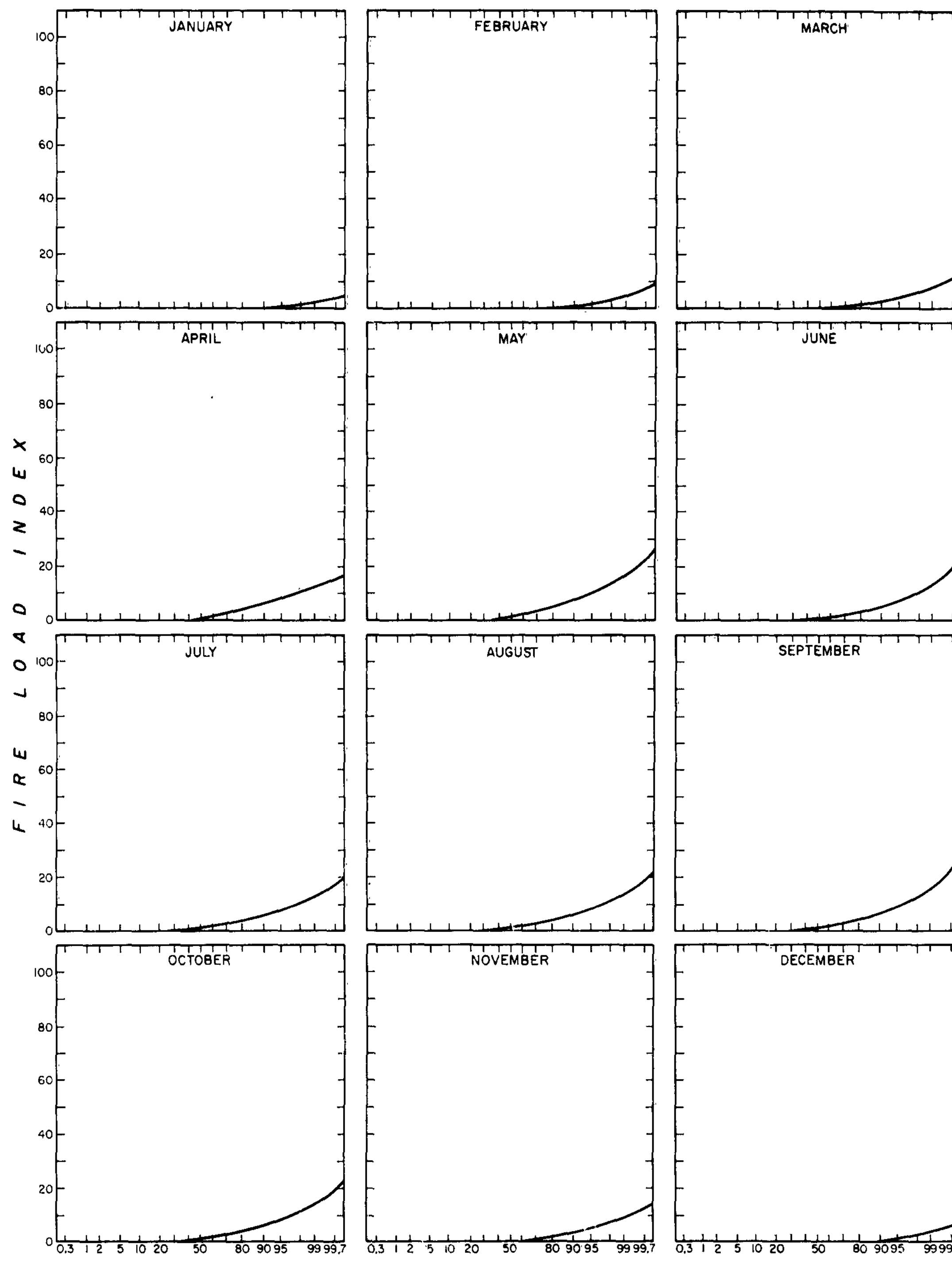
STATION 13995 SPRINGFIELD, MISSOURI



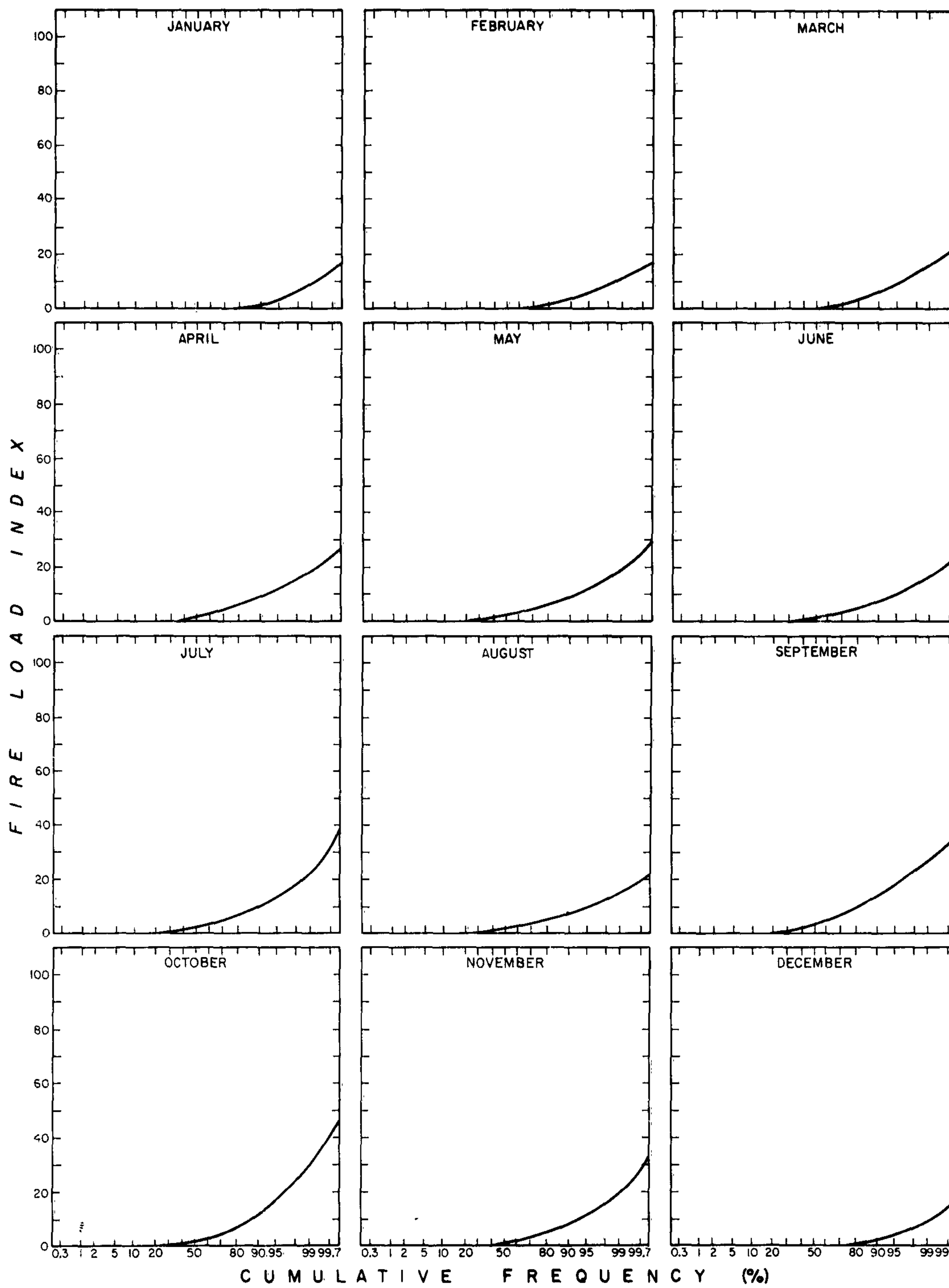
STATION 93817 EVANSVILLE, INDIANA



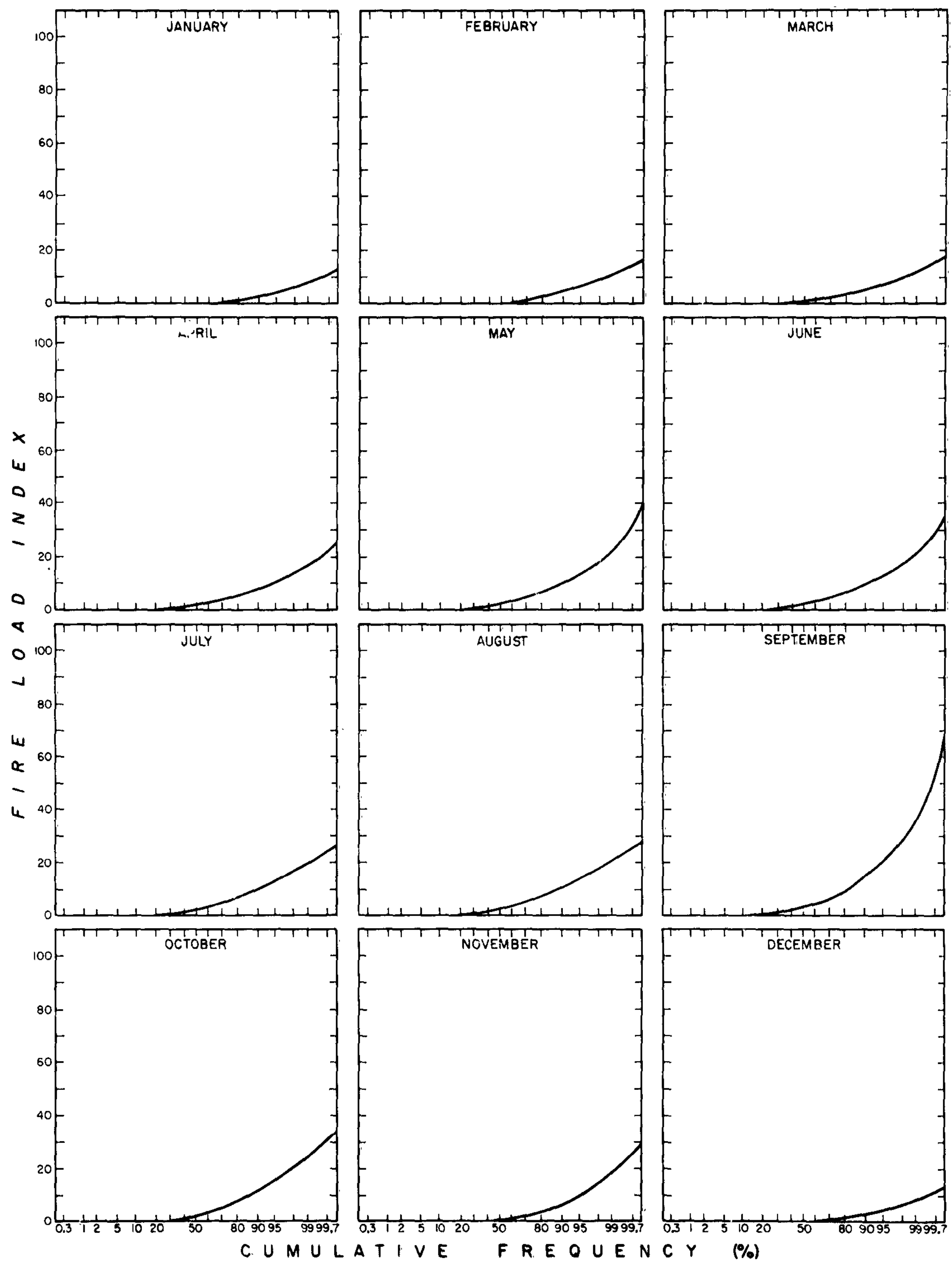
STATION 14821 COLUMBUS, OHIO



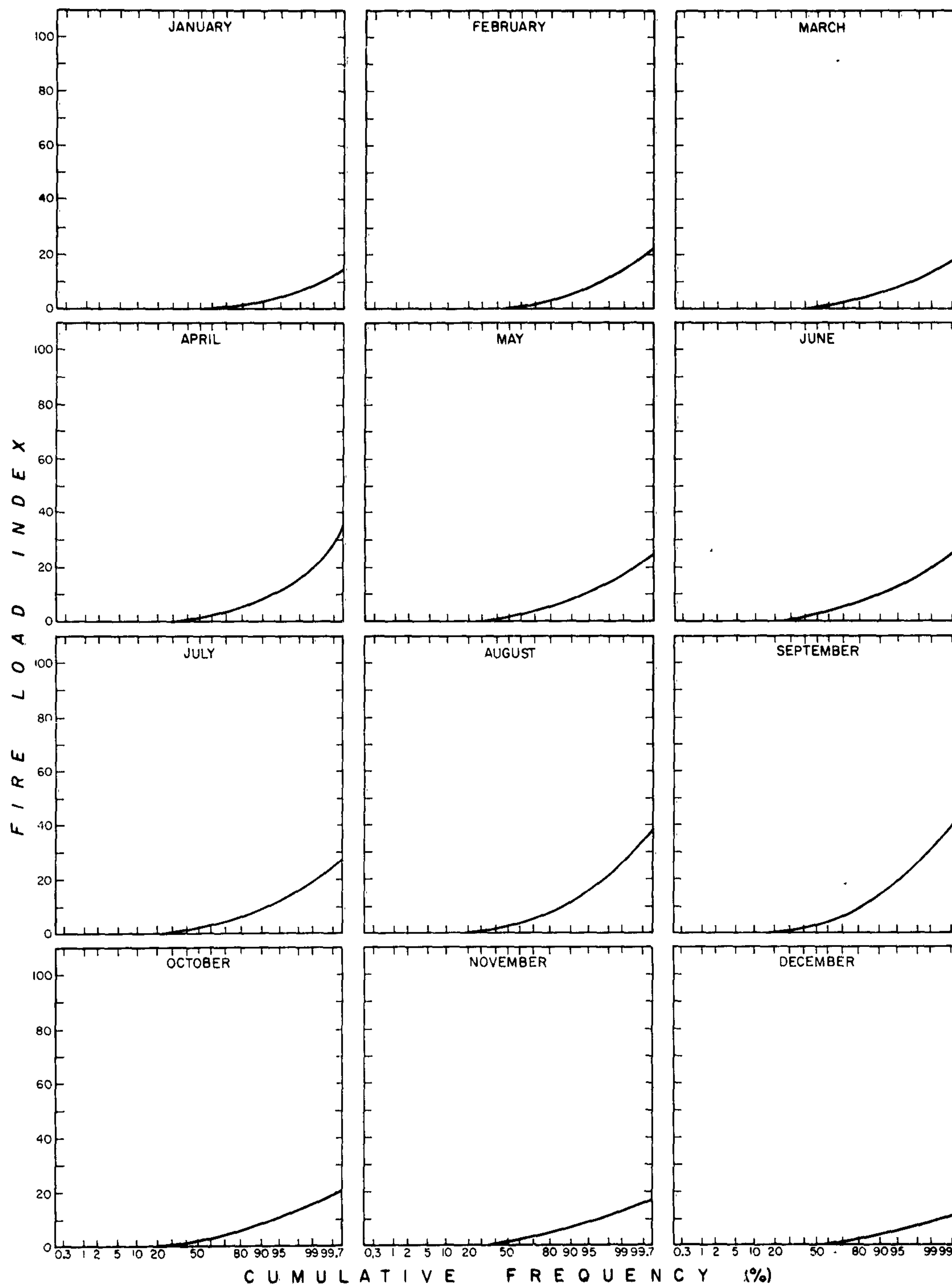
STATION 93820 LEXINGTON, KENTUCKY



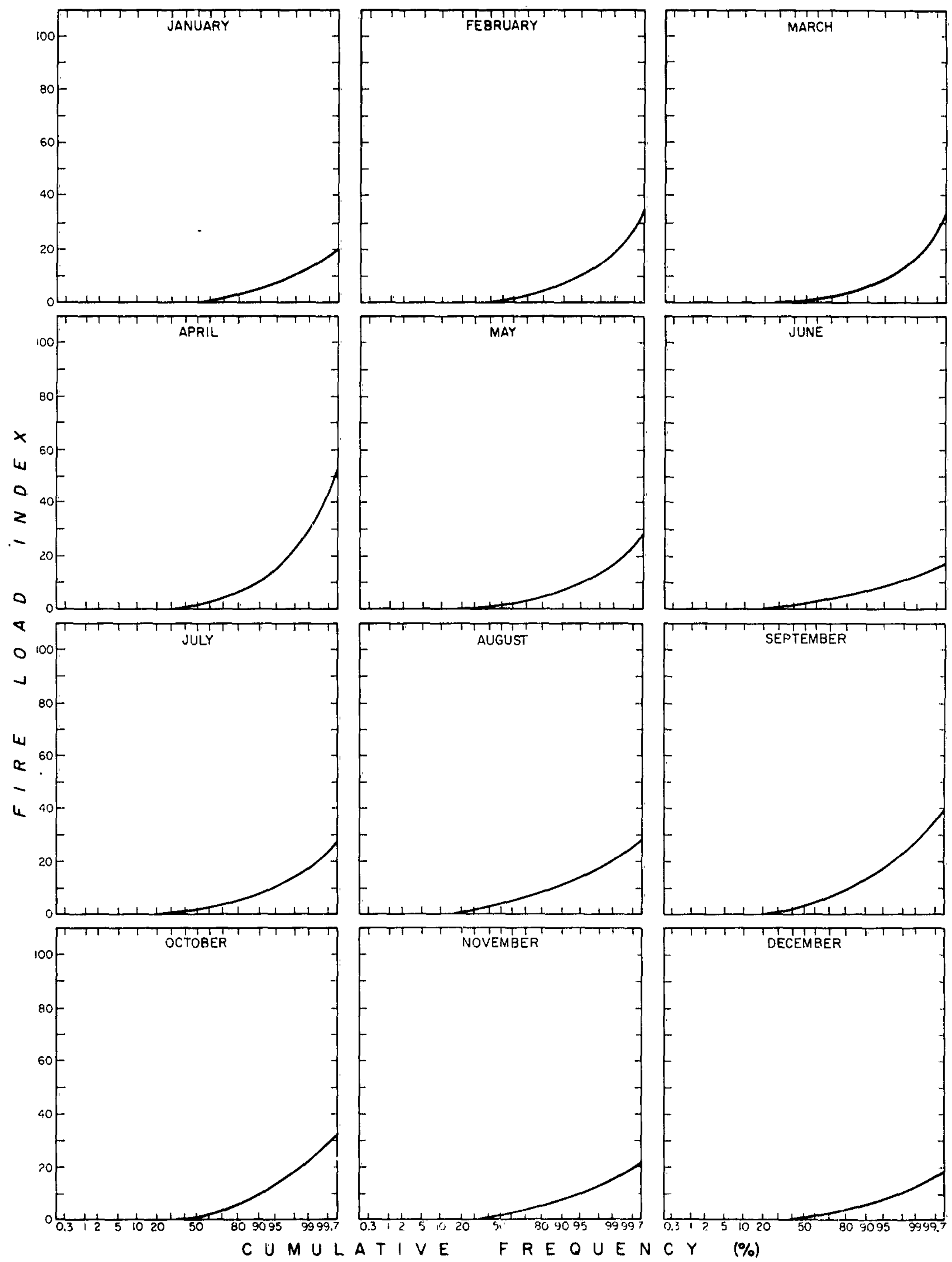
STATION 13893 MEMPHIS, TENNESSEE



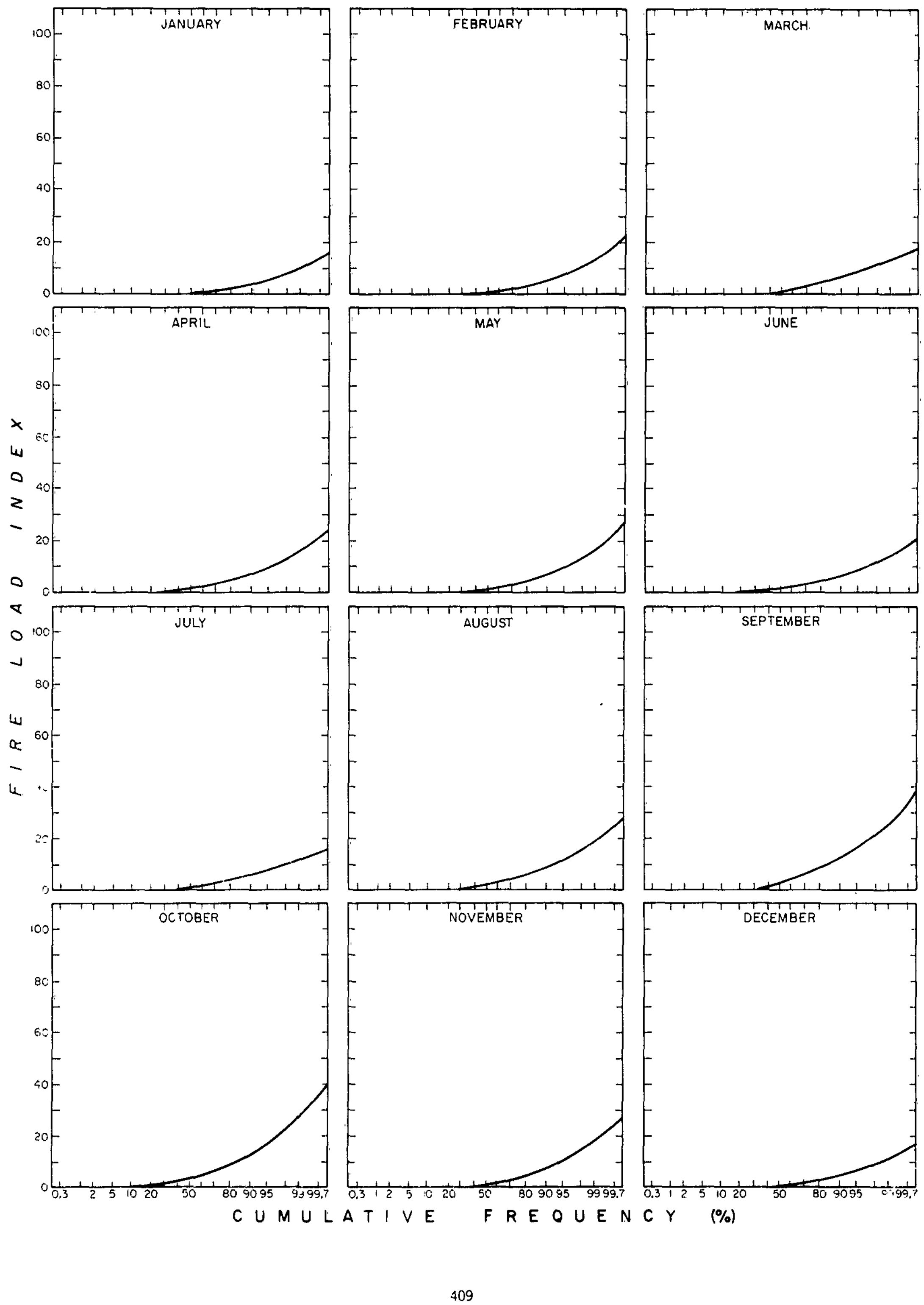
STATION 13963 LITTLE ROCK, ARKANSAS



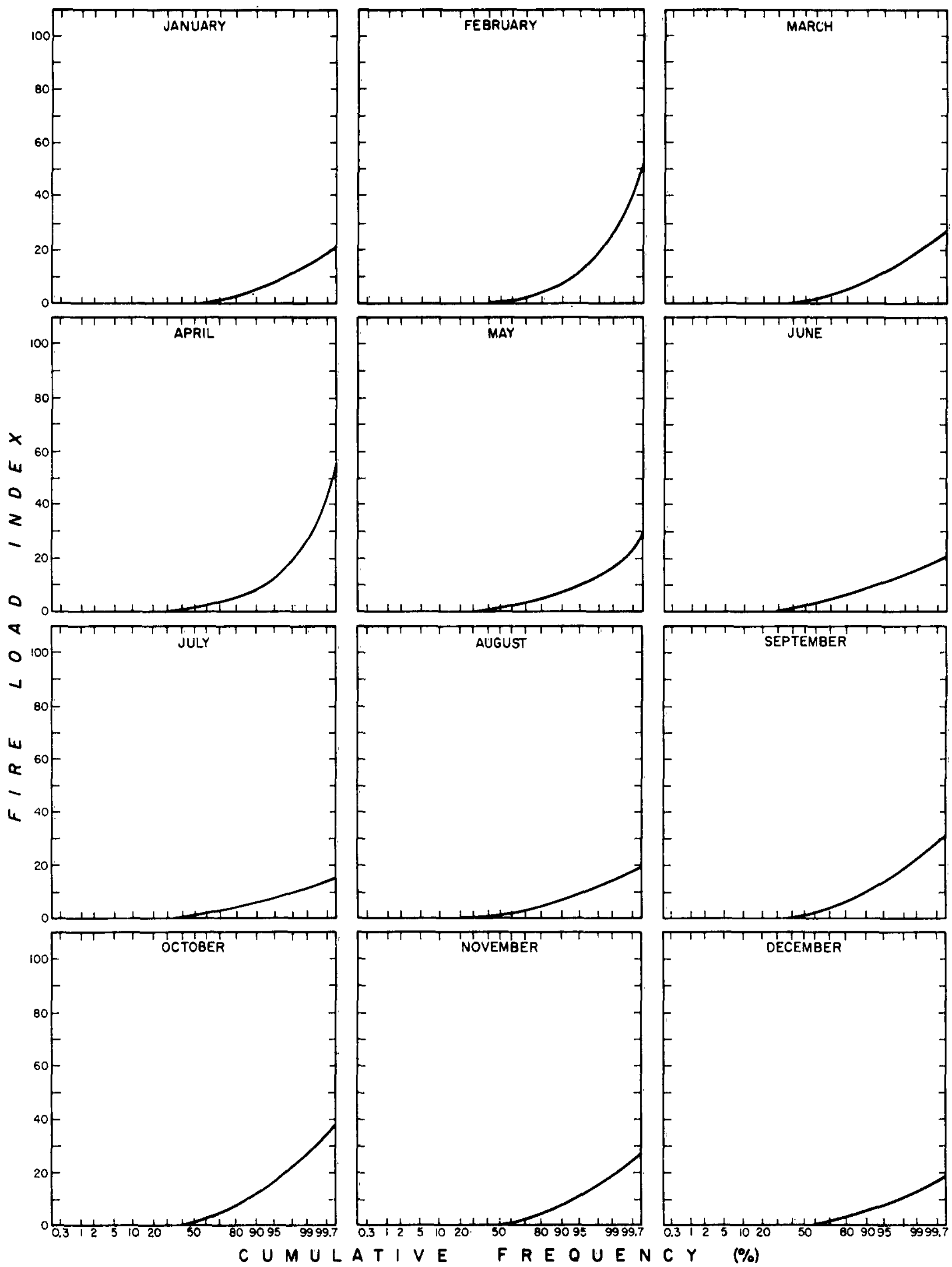
STATION 13957 SHREVEPORT, LOUISIANA



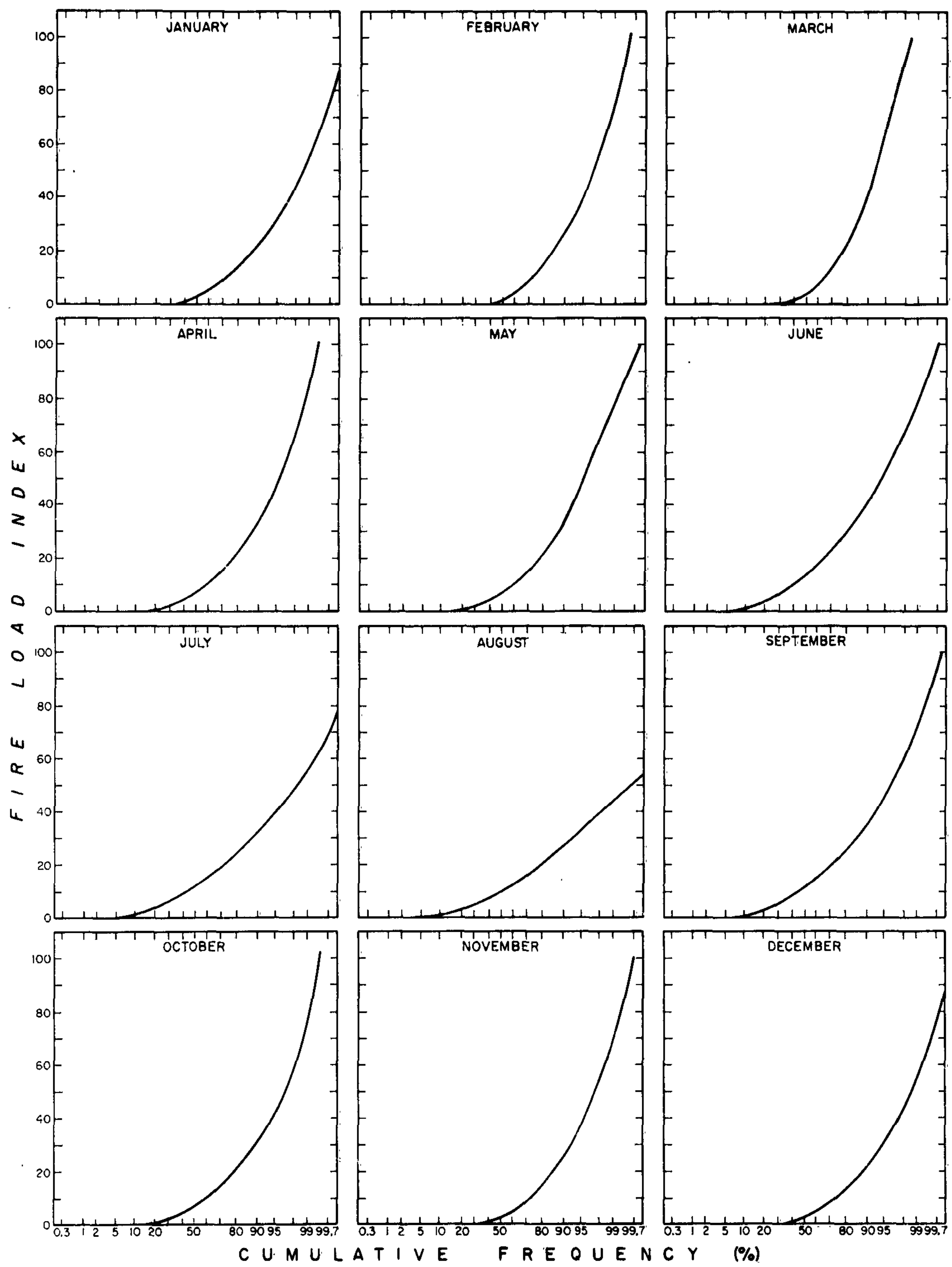
STATION 13956 JACKSON, MISSISSIPPI



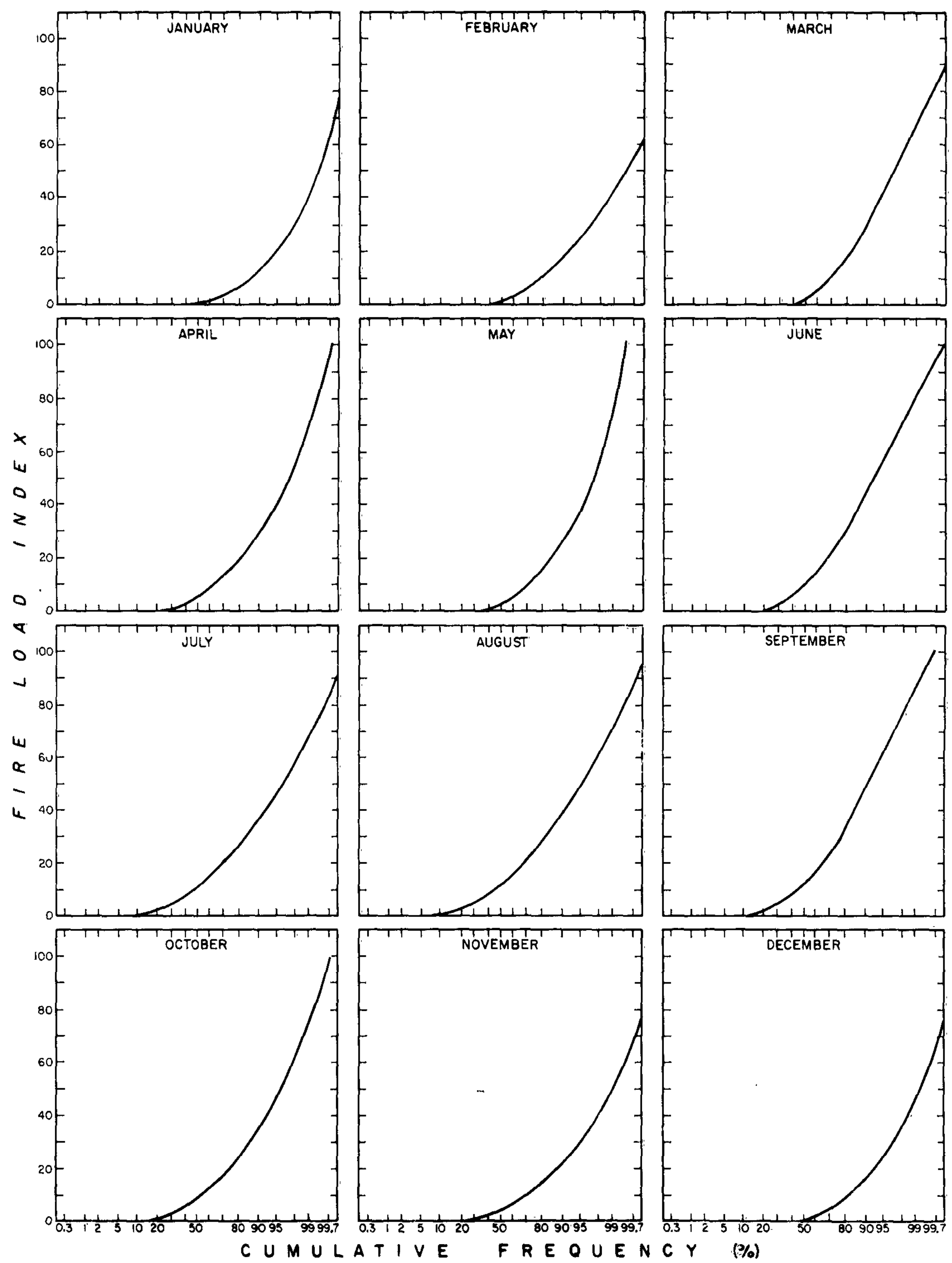
STATION 12918 HOUSTON, TEXAS



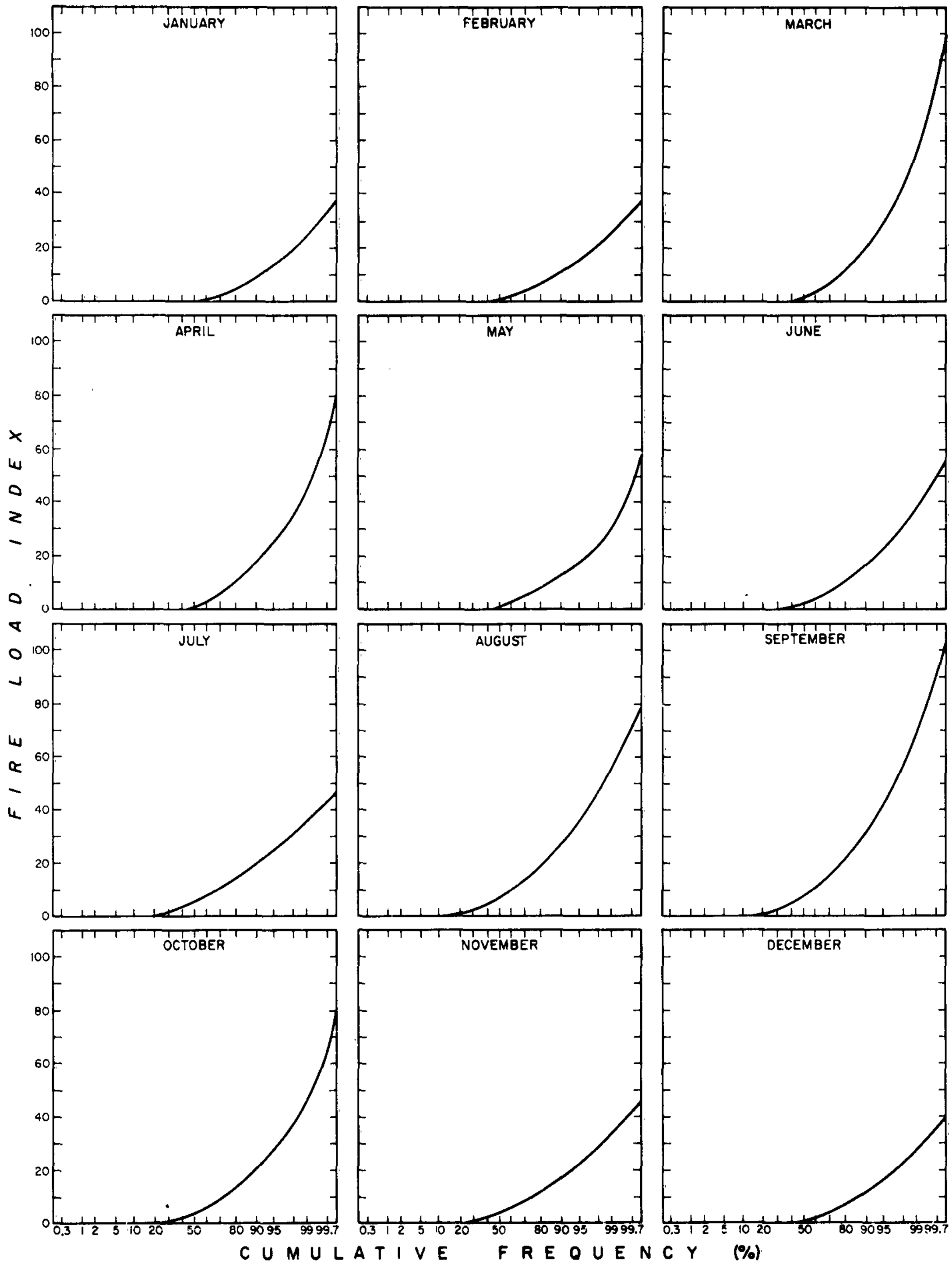
STATION 93058 PUEBLO, COLORADO



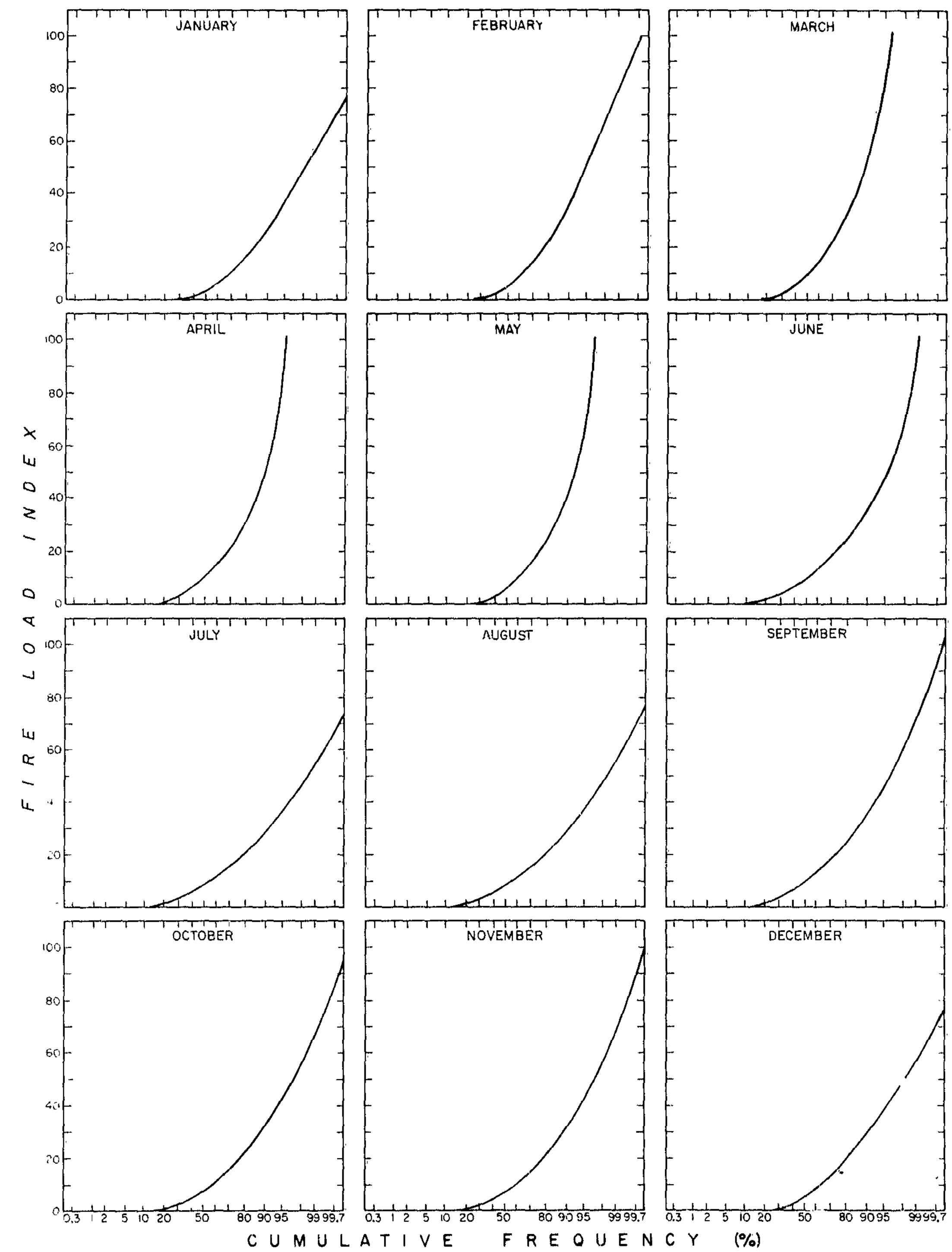
STATION 13985 DODGE CITY, KANSAS



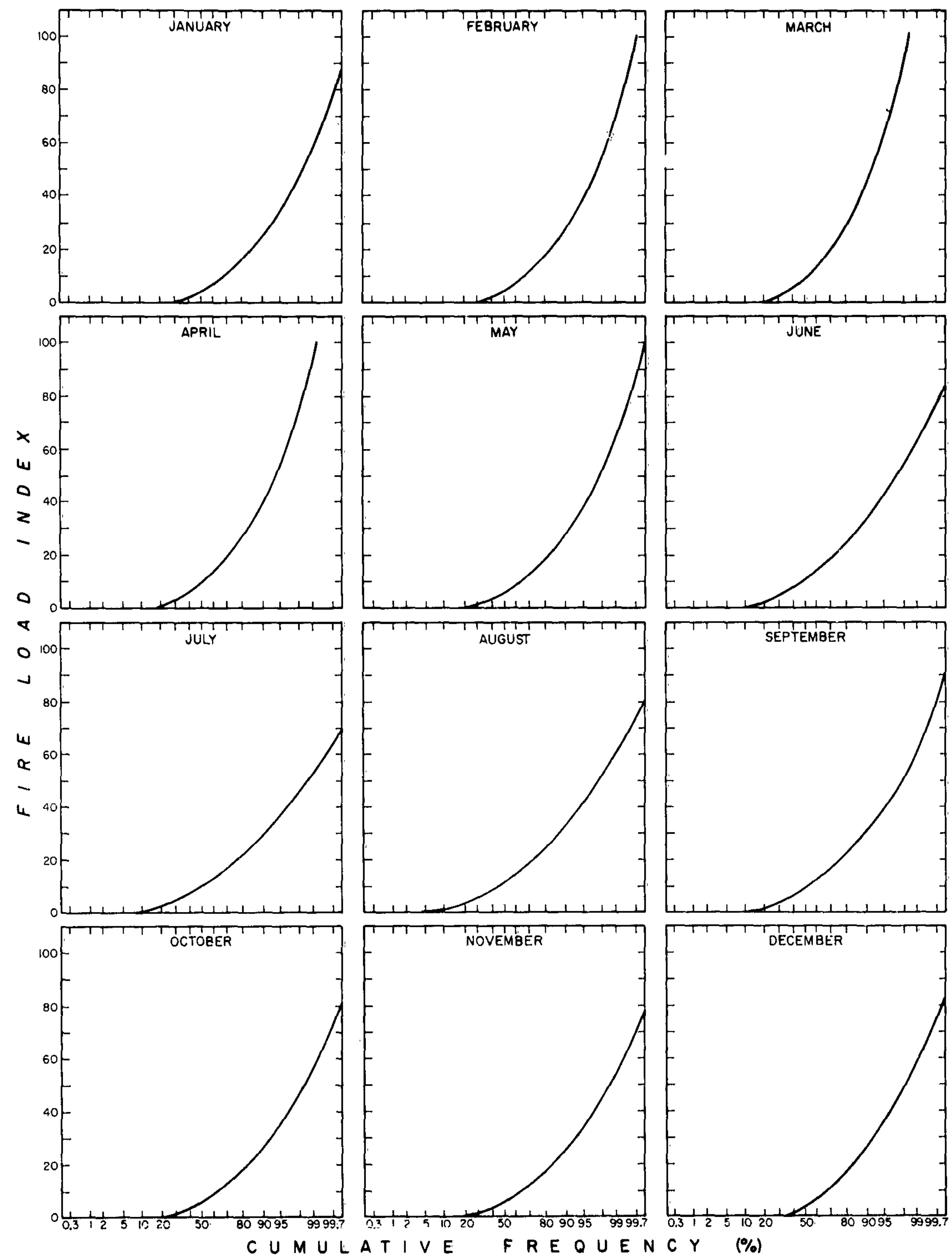
STATION 13967 OKLAHOMA CITY, OKLAHOMA



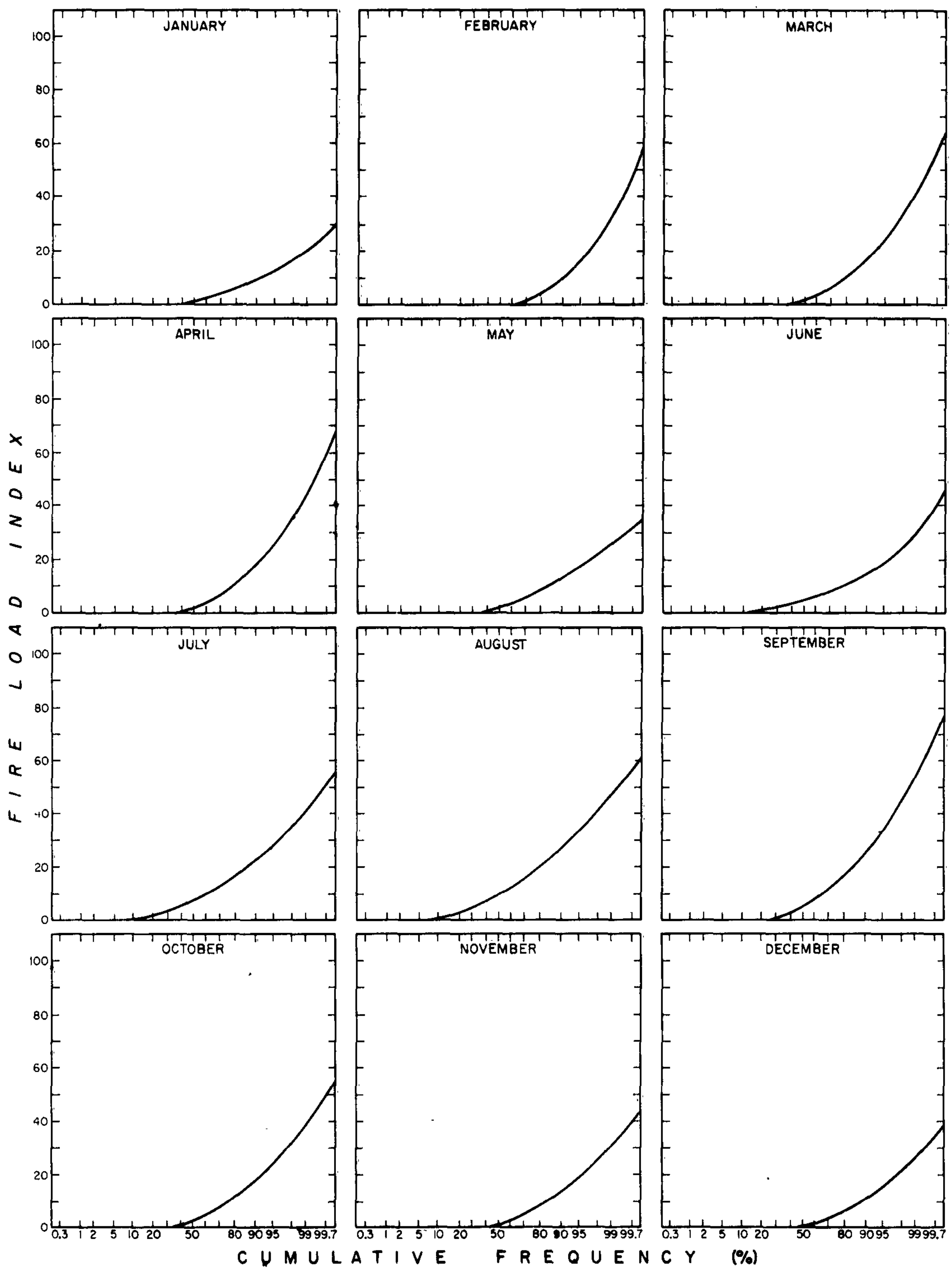
STATION 23047 AMARILLO, TEXAS



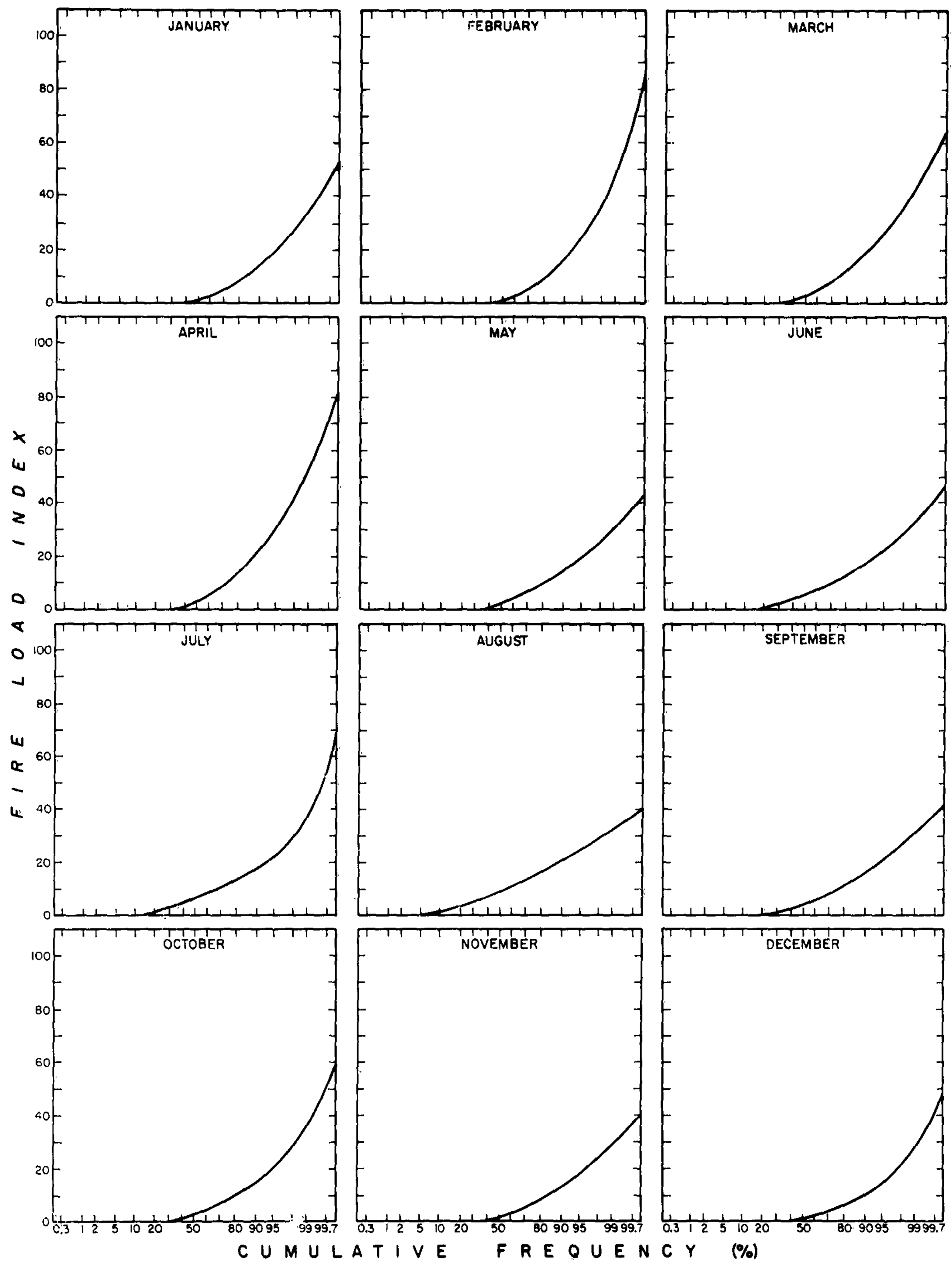
STATION 13962 ABILENE, TEXAS



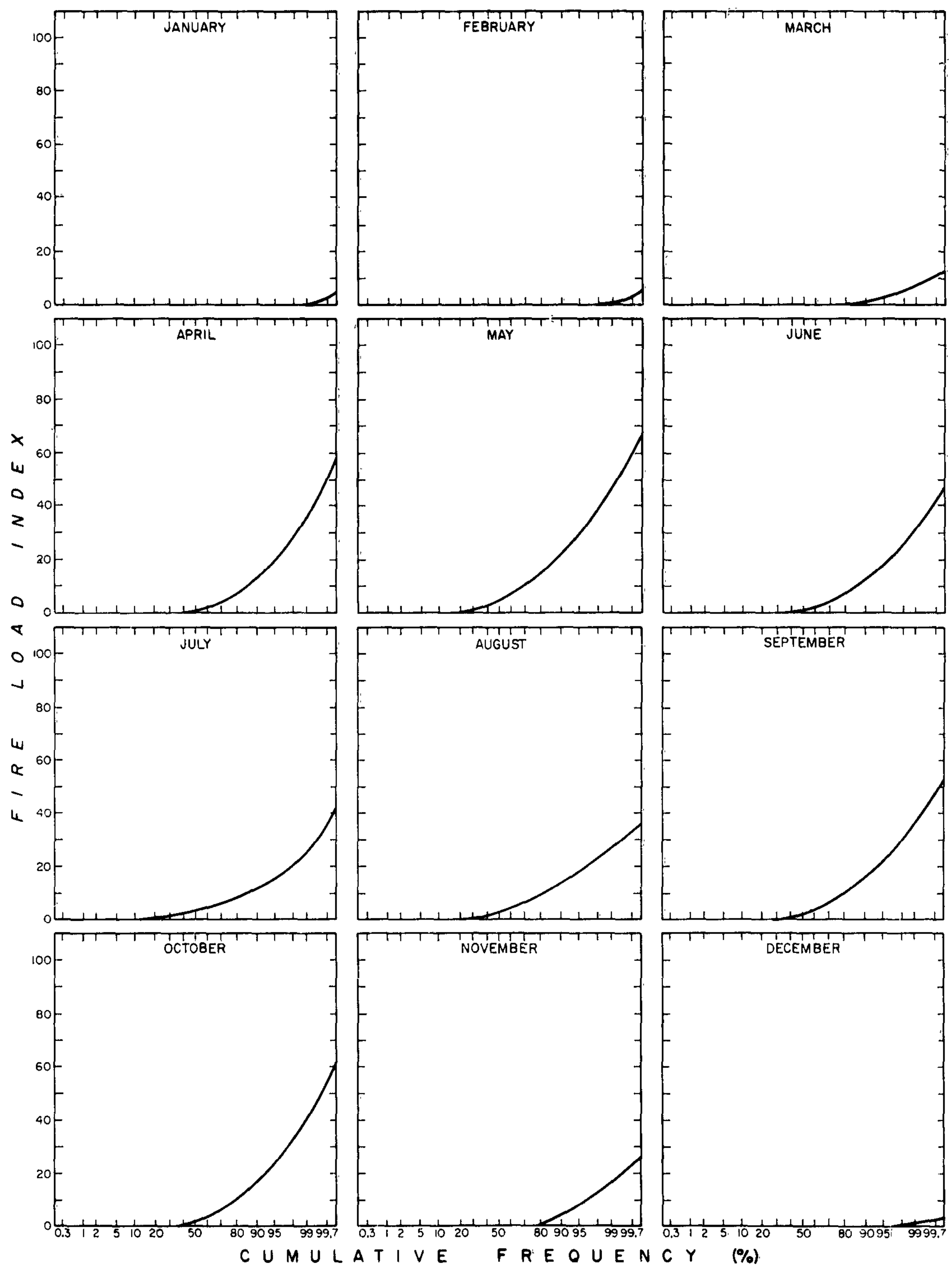
STATION 13959 WACO, TEXAS



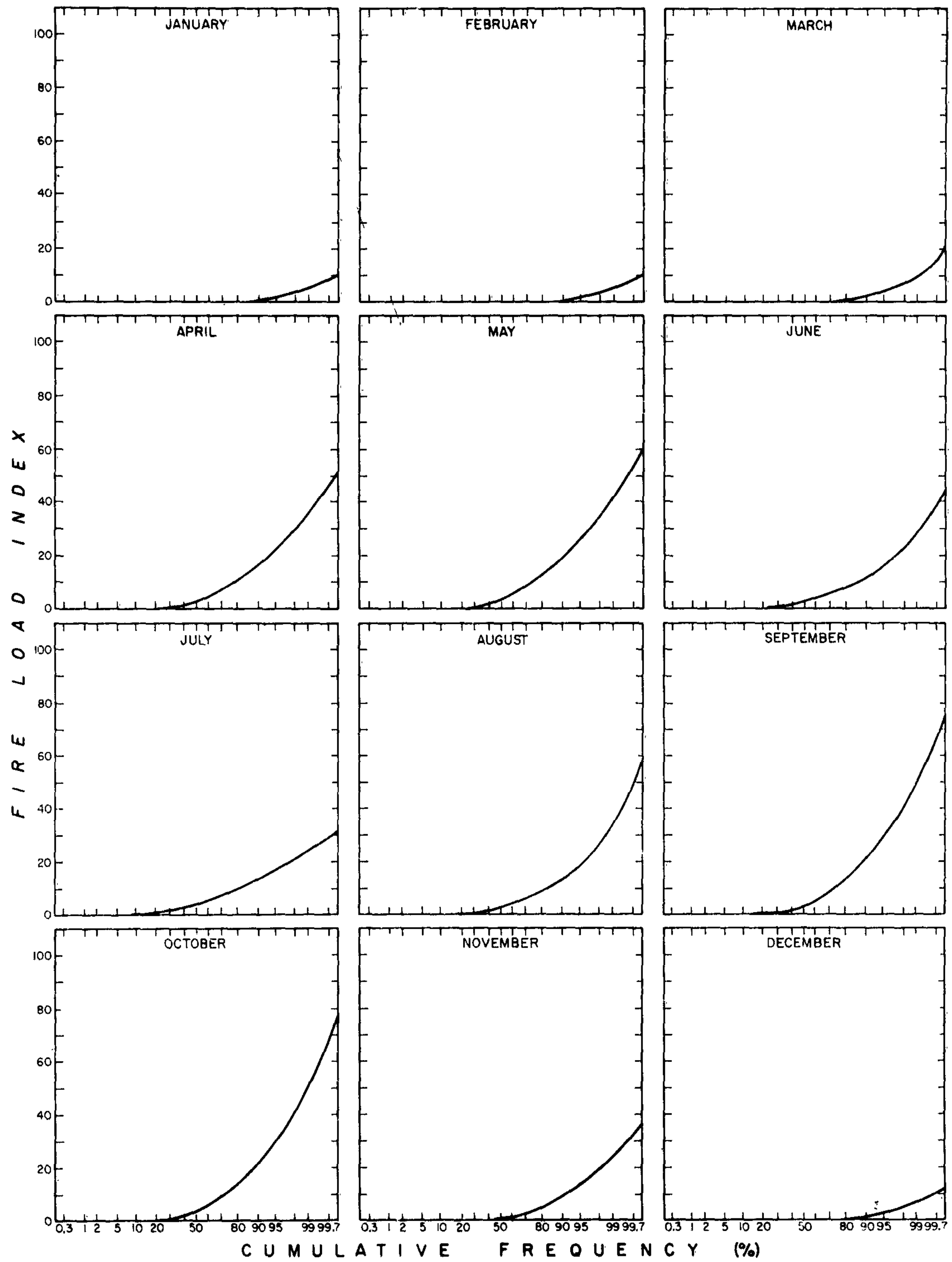
STATION 12921 SAN ANTONIO, TEXAS



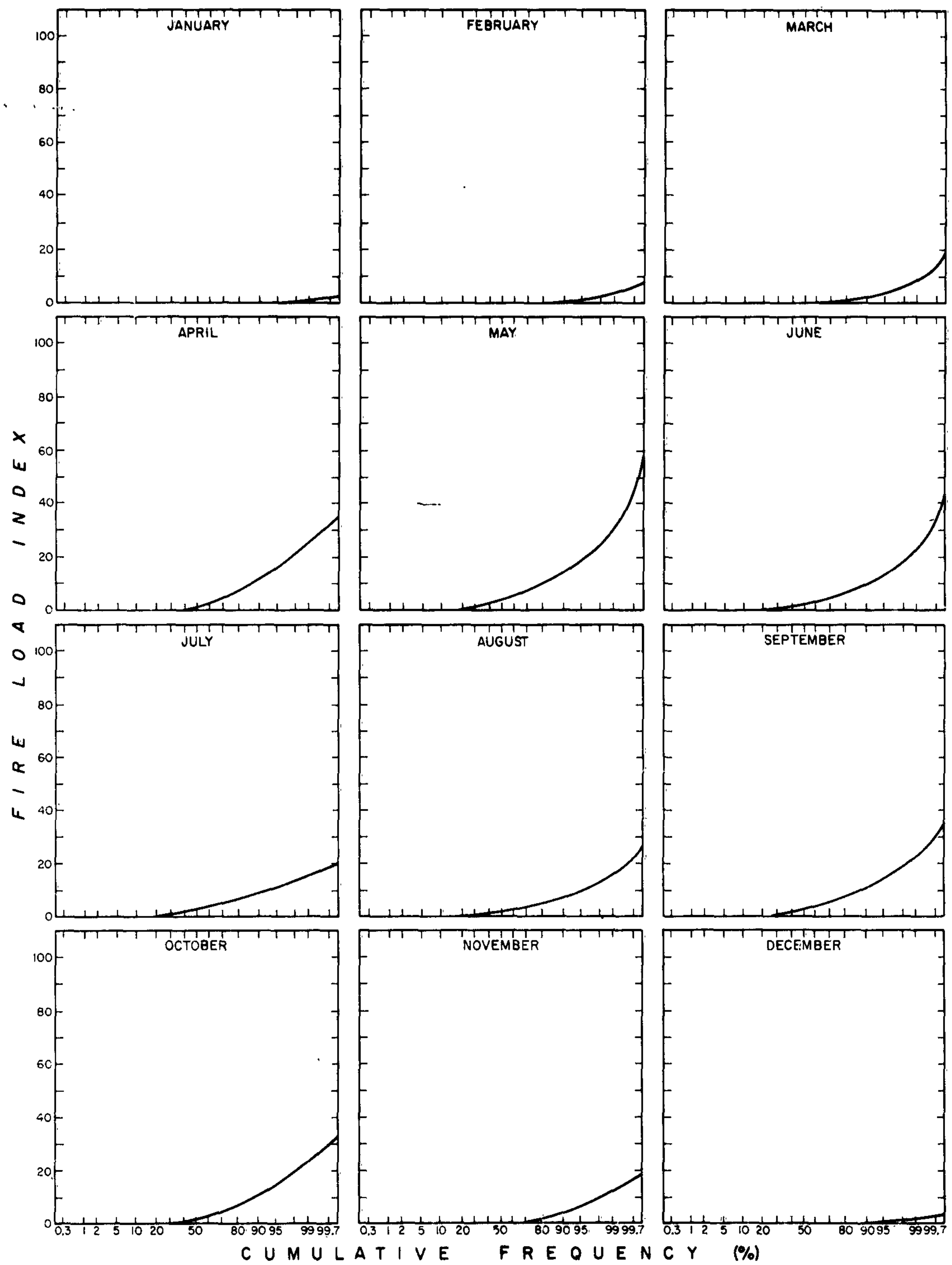
STATION 14914 FARGO, NORTH DAKOTA



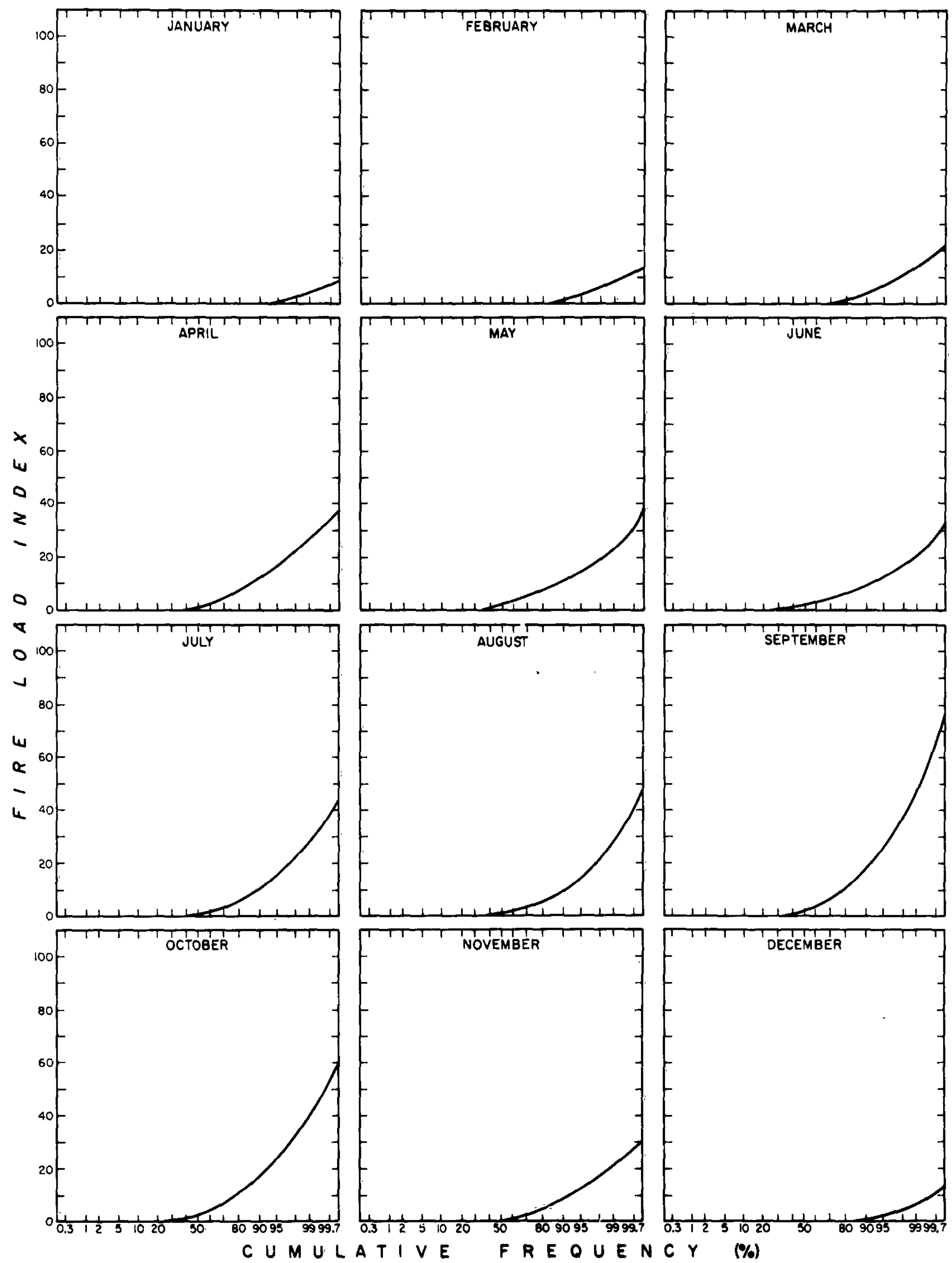
STATION 14944 SIOUX FALLS, SOUTH DAKOTA



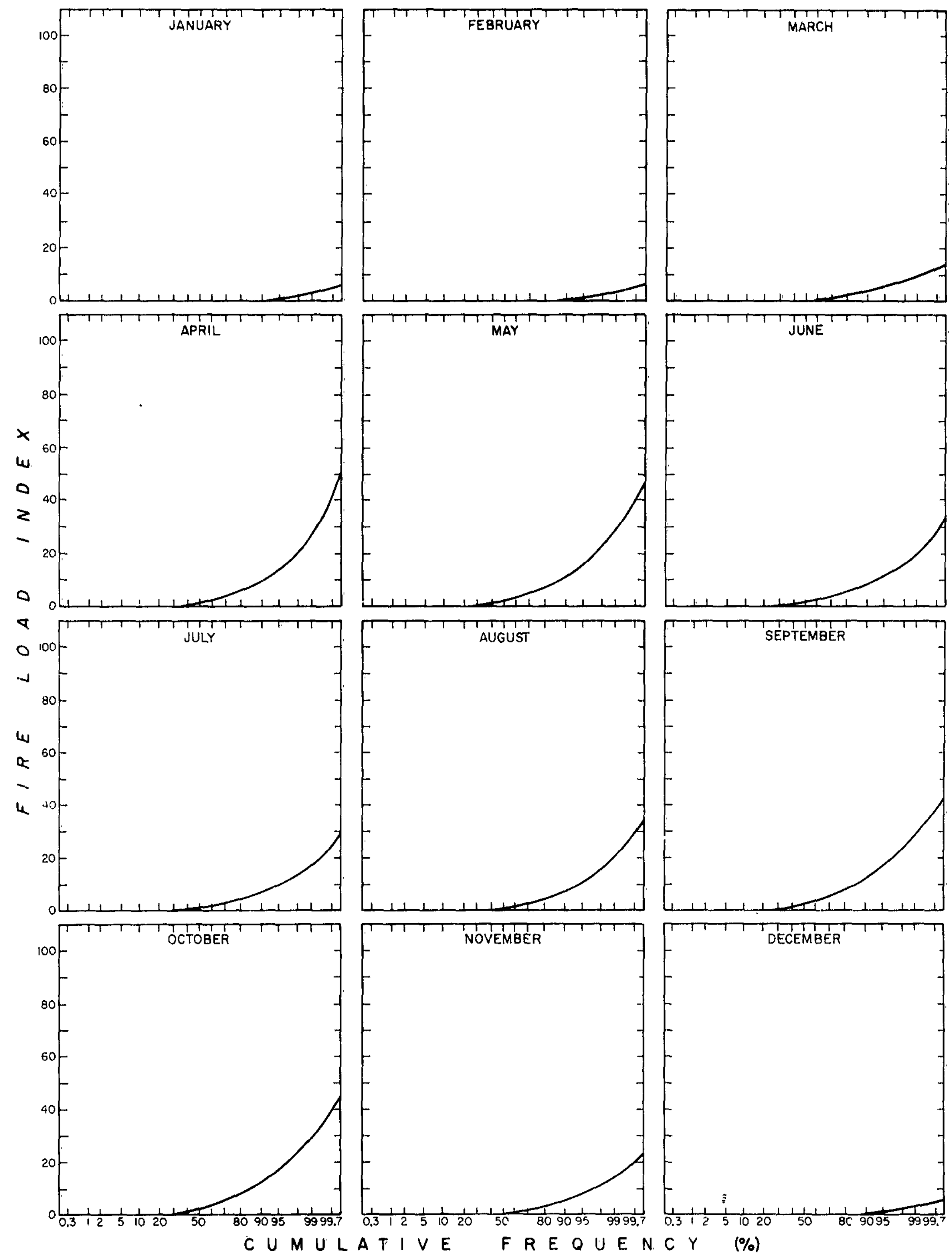
STATION 14922 MINNEAPOLIS, MINNESOTA



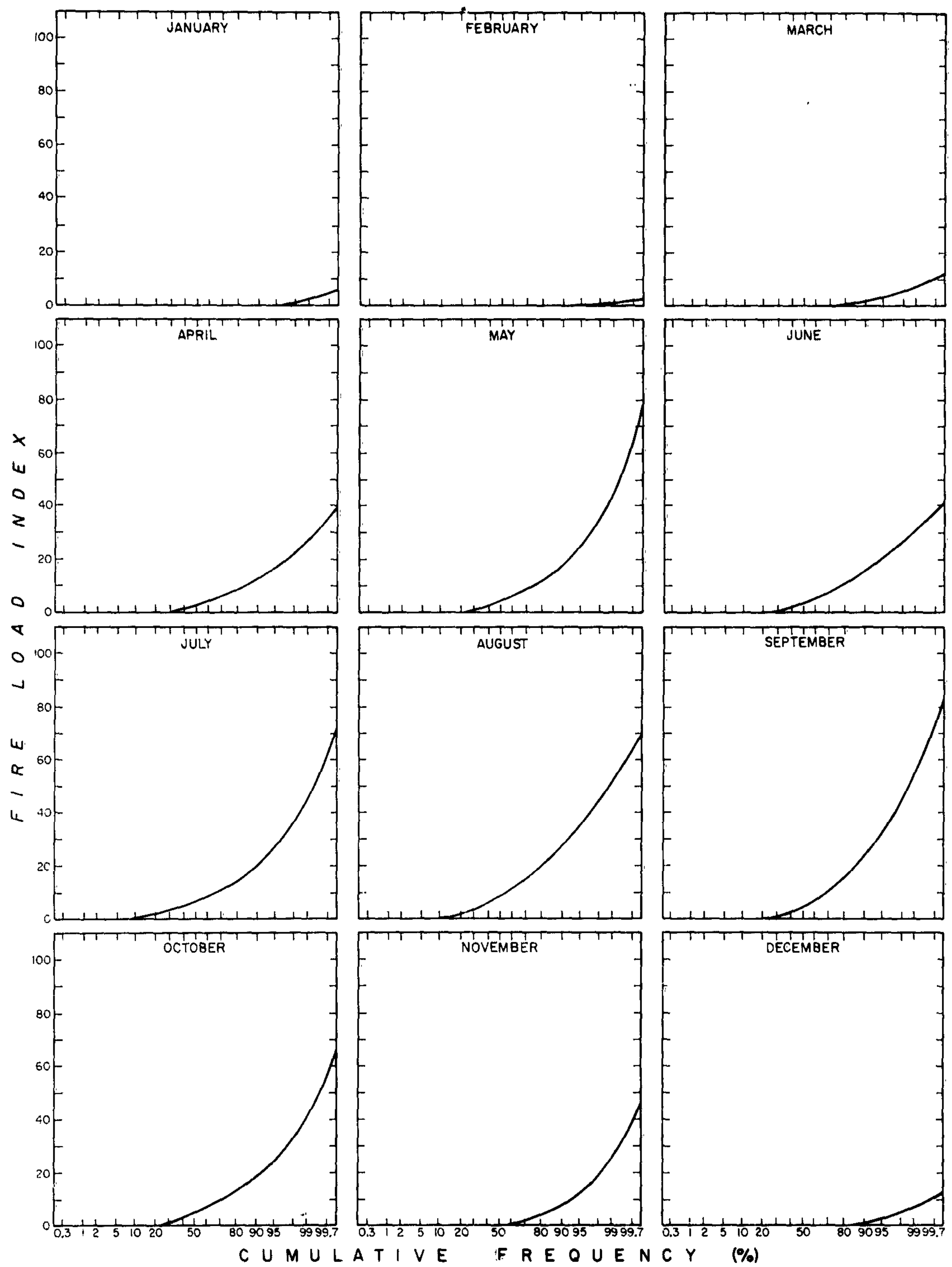
STATION 14933 DES MOINES, IOWA



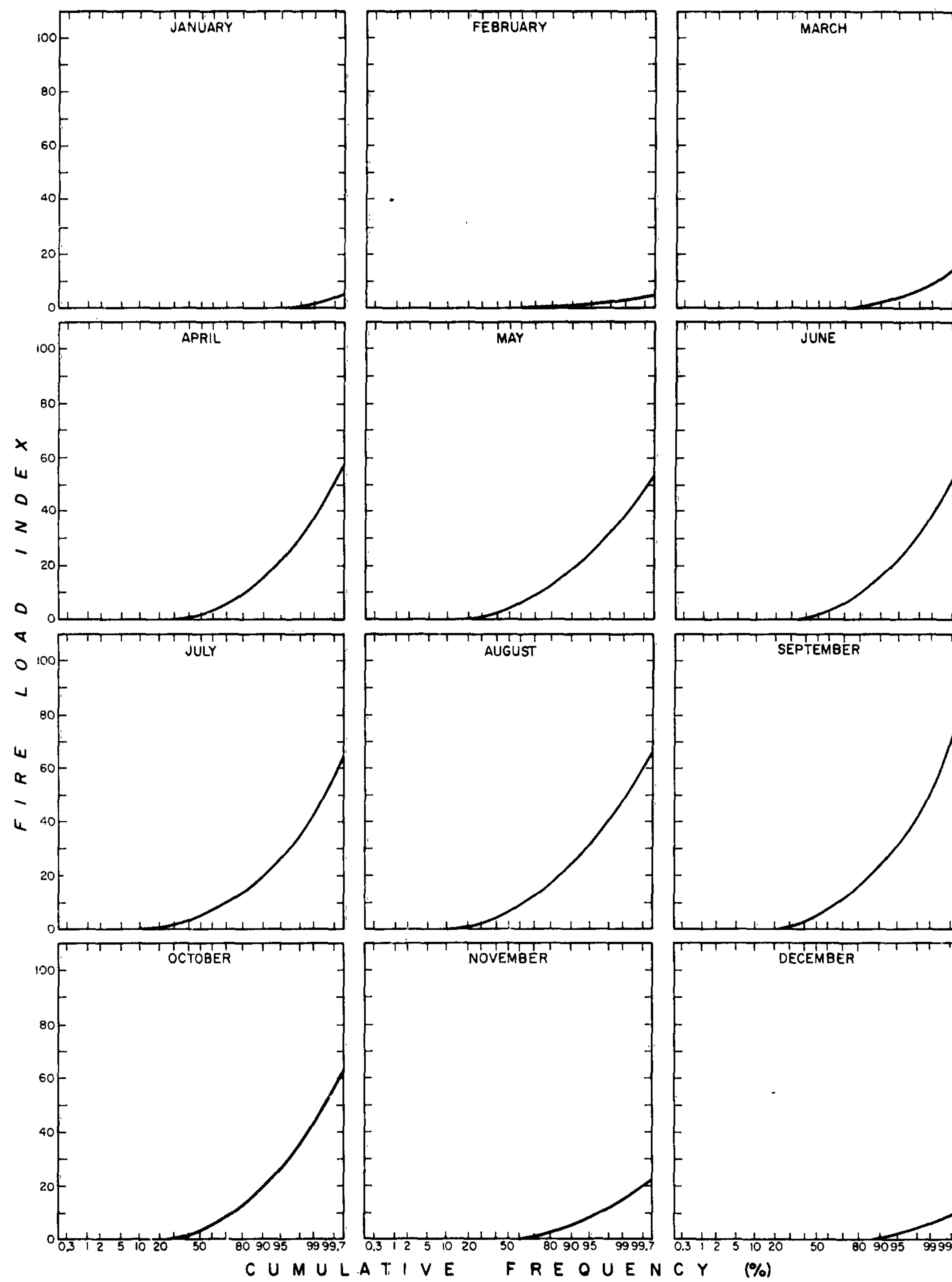
STATION 14923 MOLINE, ILLINOIS



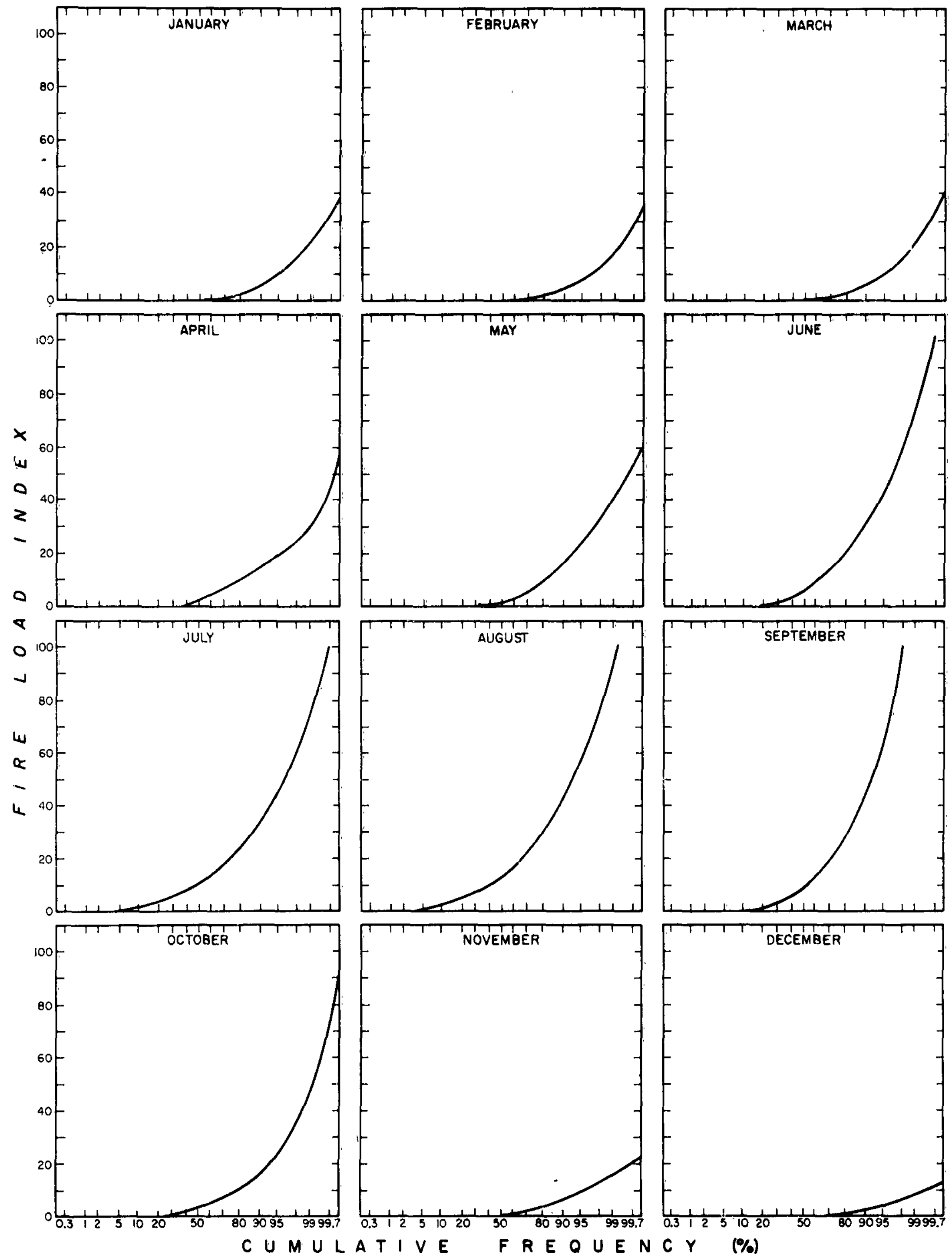
STATION 94008 GLASGOW, MONTANA



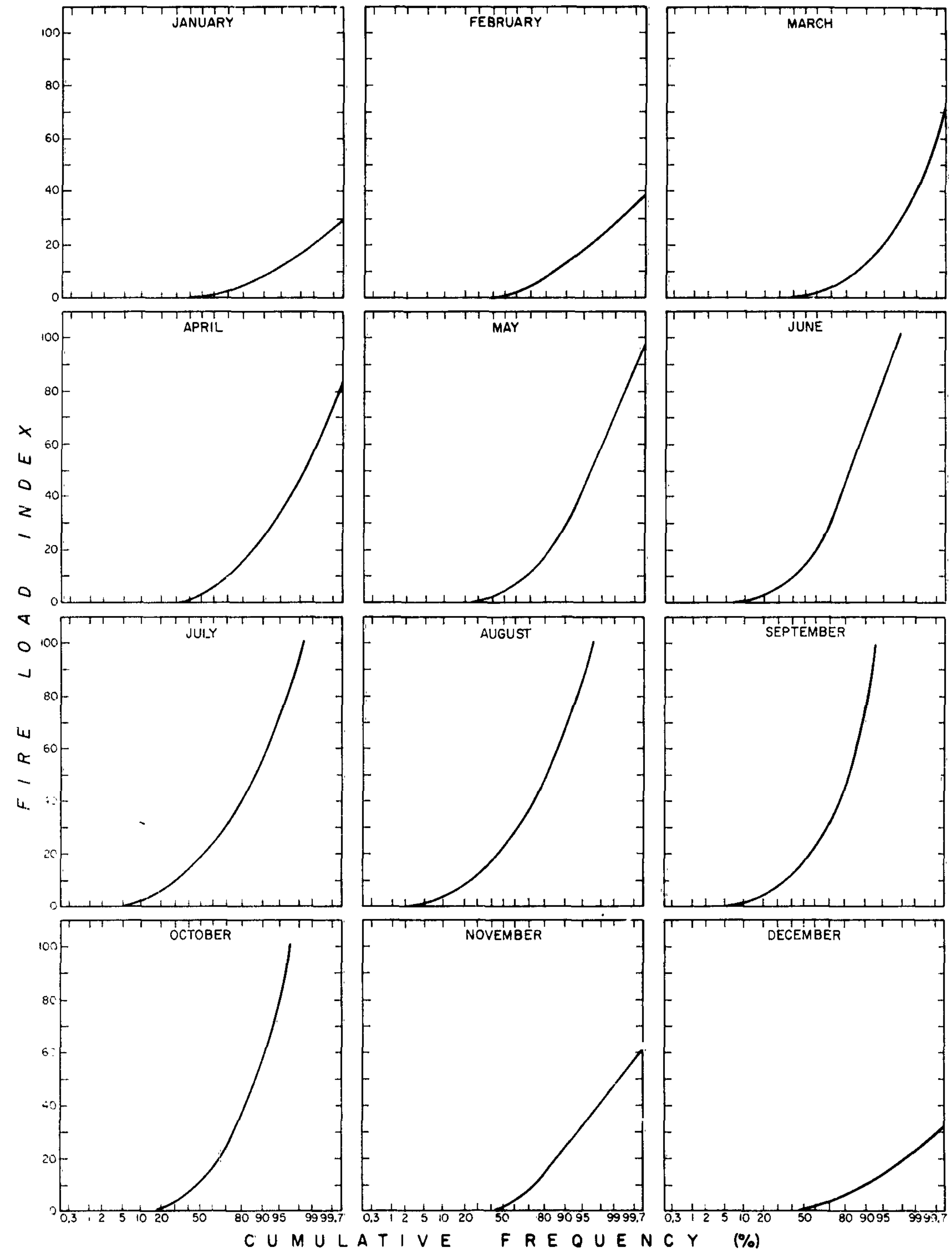
STATION 24011 BISMARCK, NORTH DAKOTA



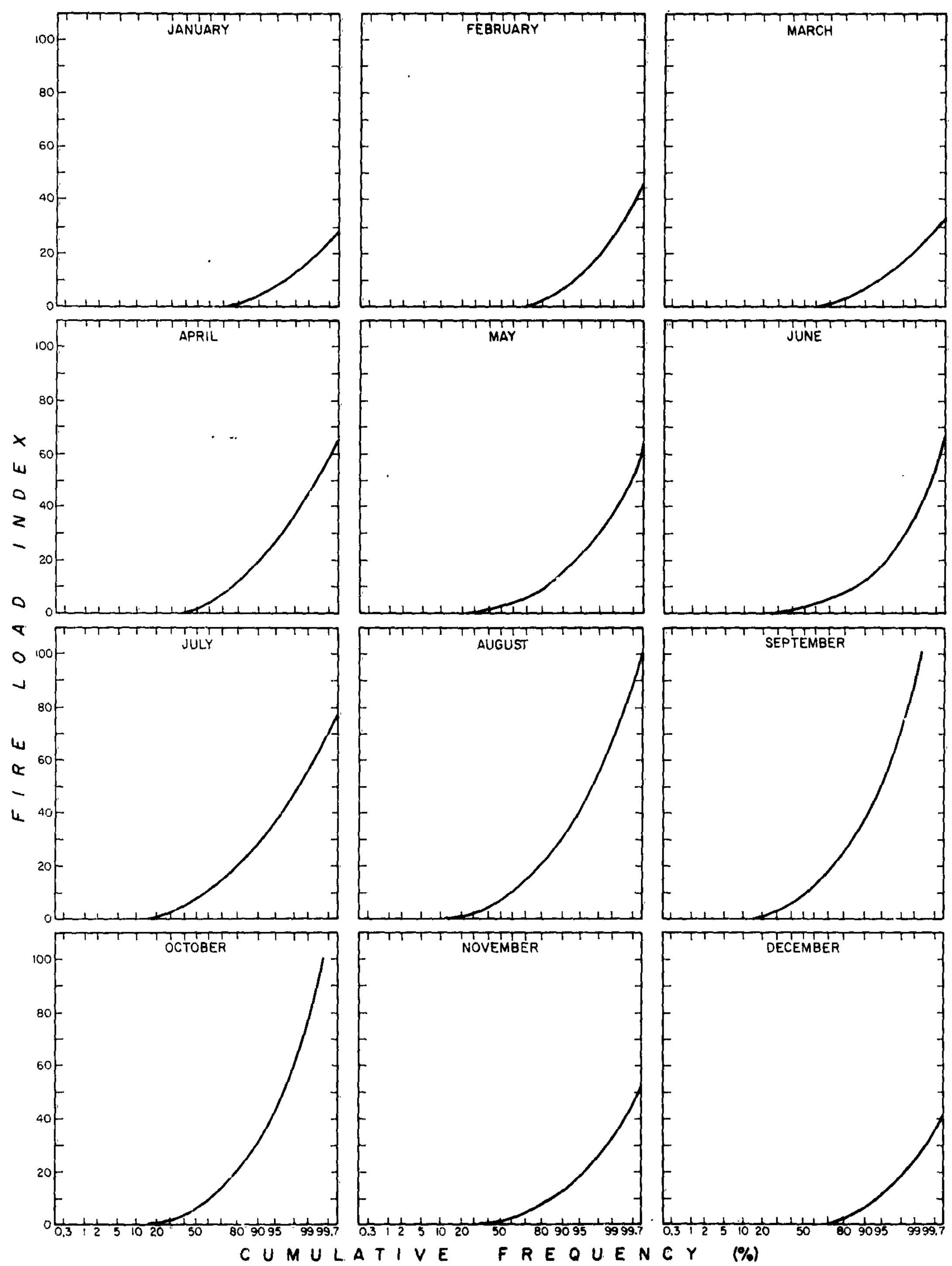
STATION 24021 LANDER, WYOMING



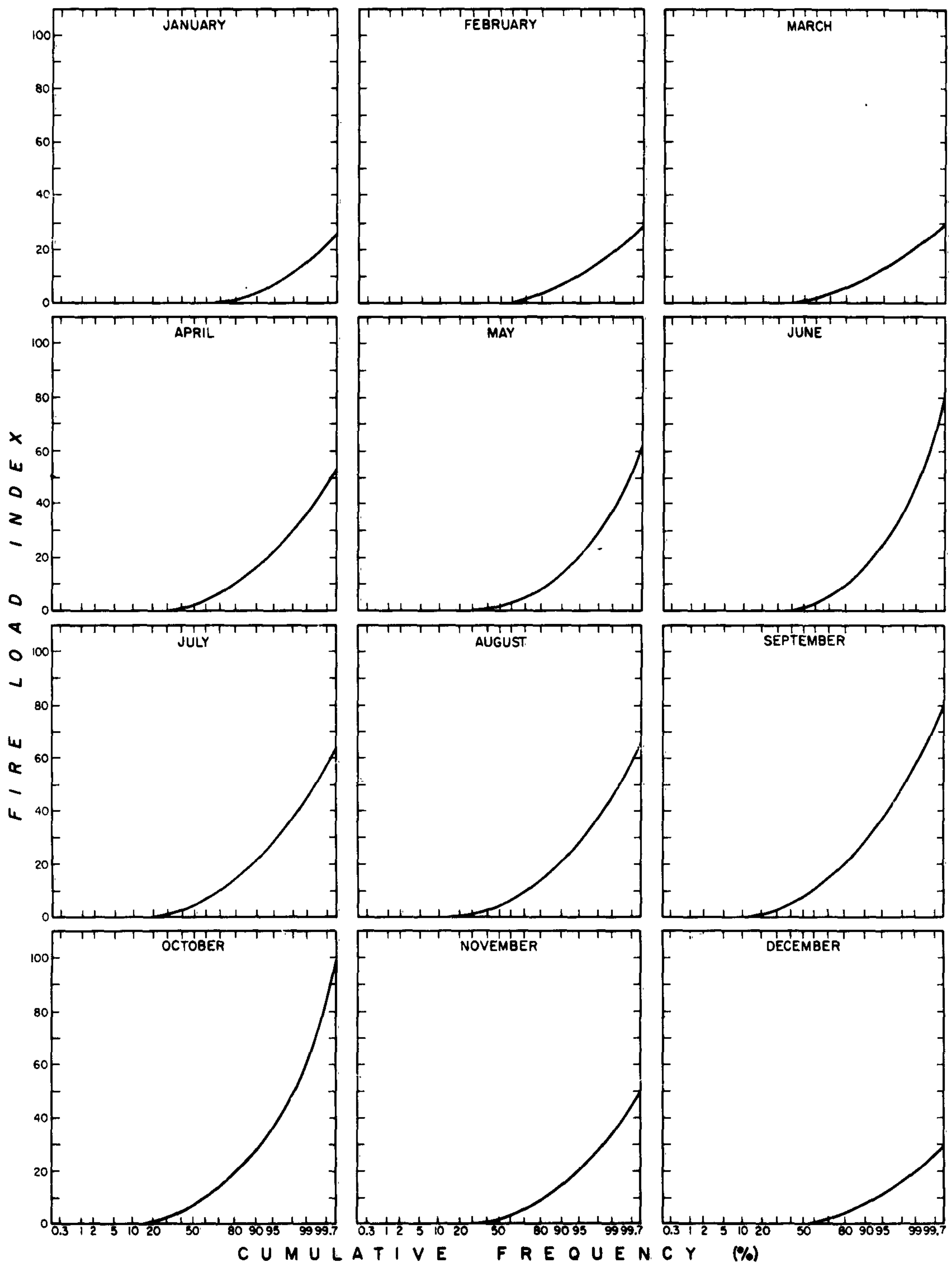
STATION 24089 CASPER, WYOMING



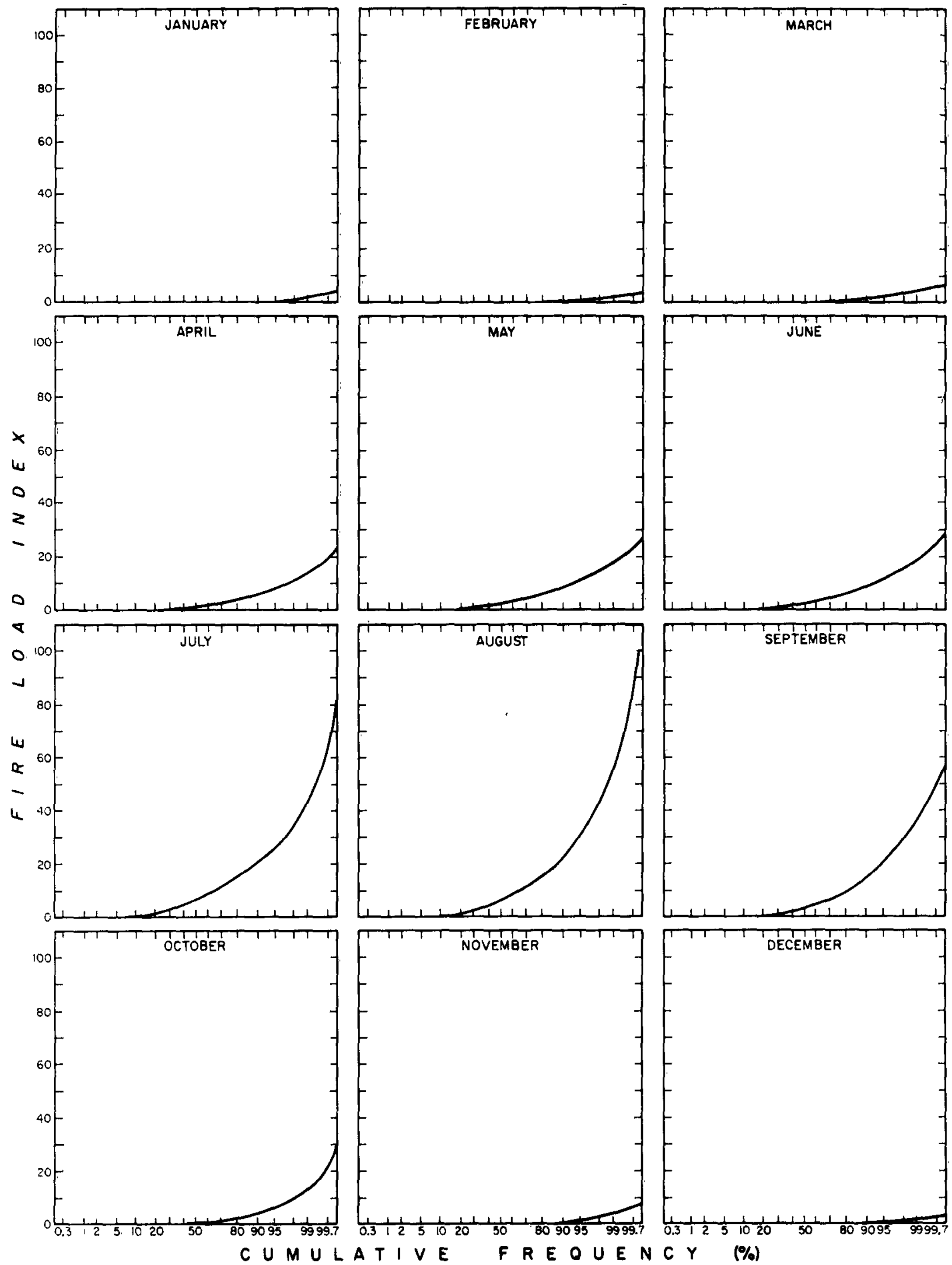
STATION 24090 RAPID CITY, SOUTH DAKOTA



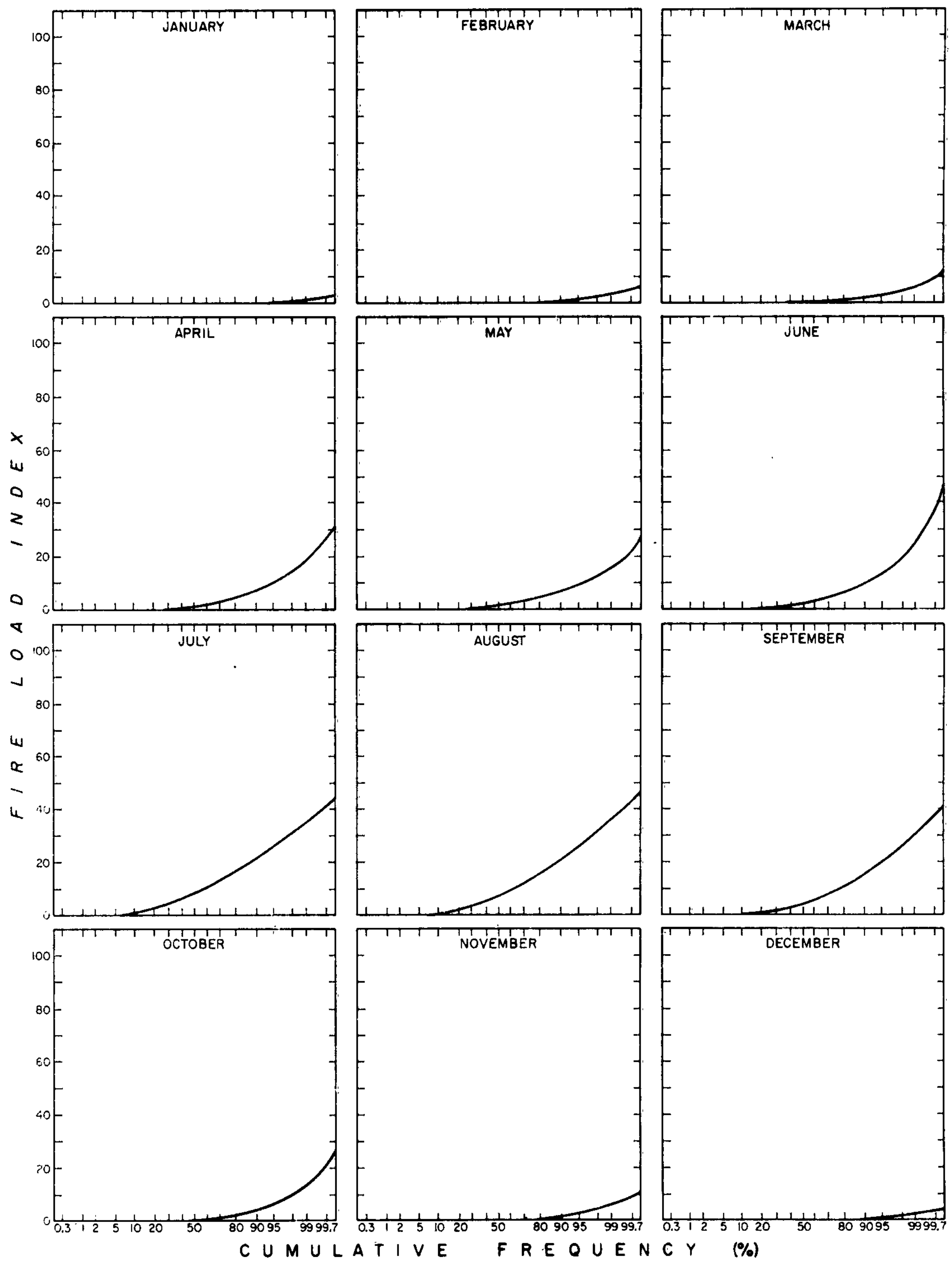
STATION 24023 NORTH PLATTE, NEBRASKA



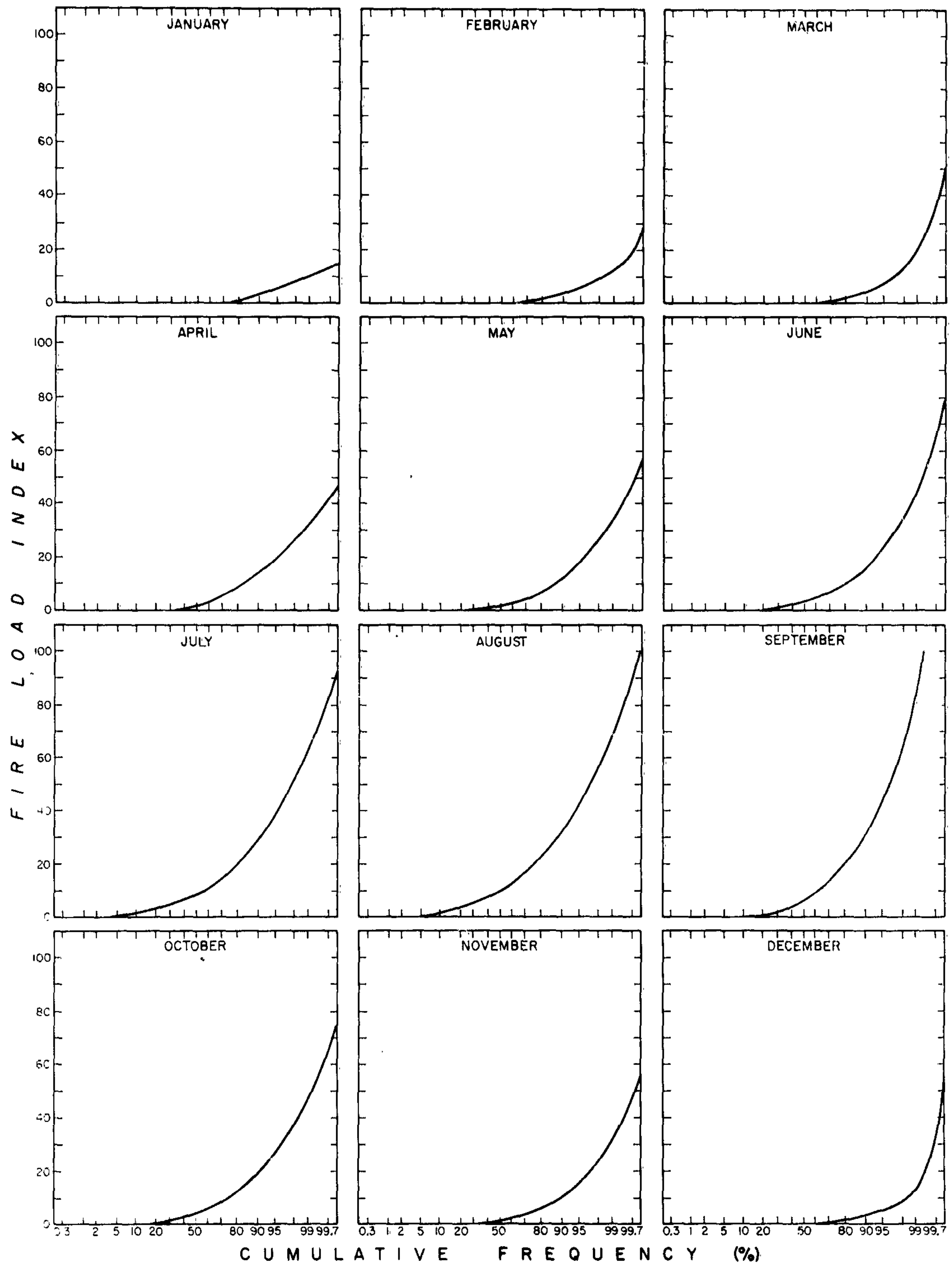
STATION 24146 KALISPELL, MONTANA



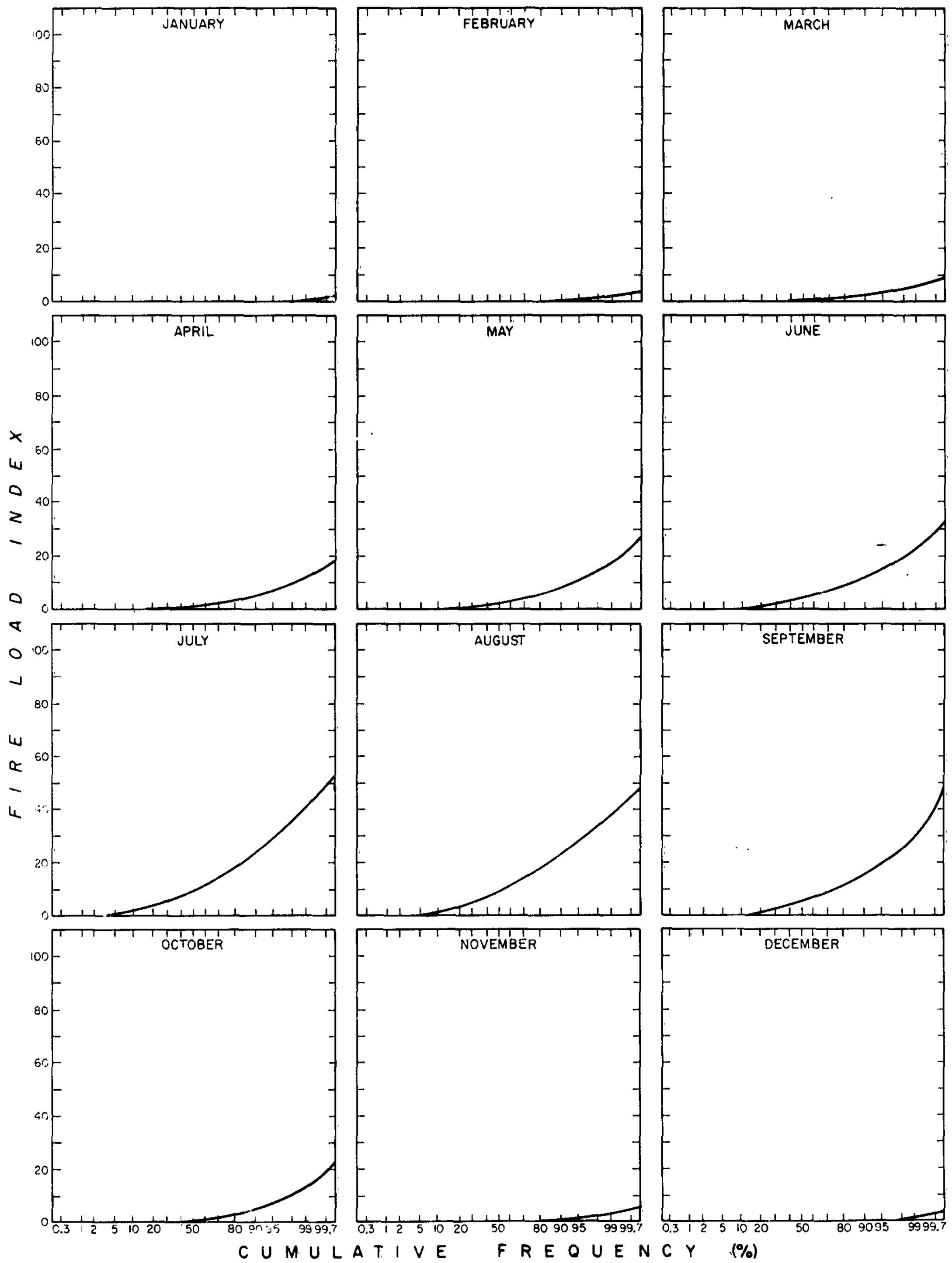
STATION 24153 MISSOULA, MONTANA



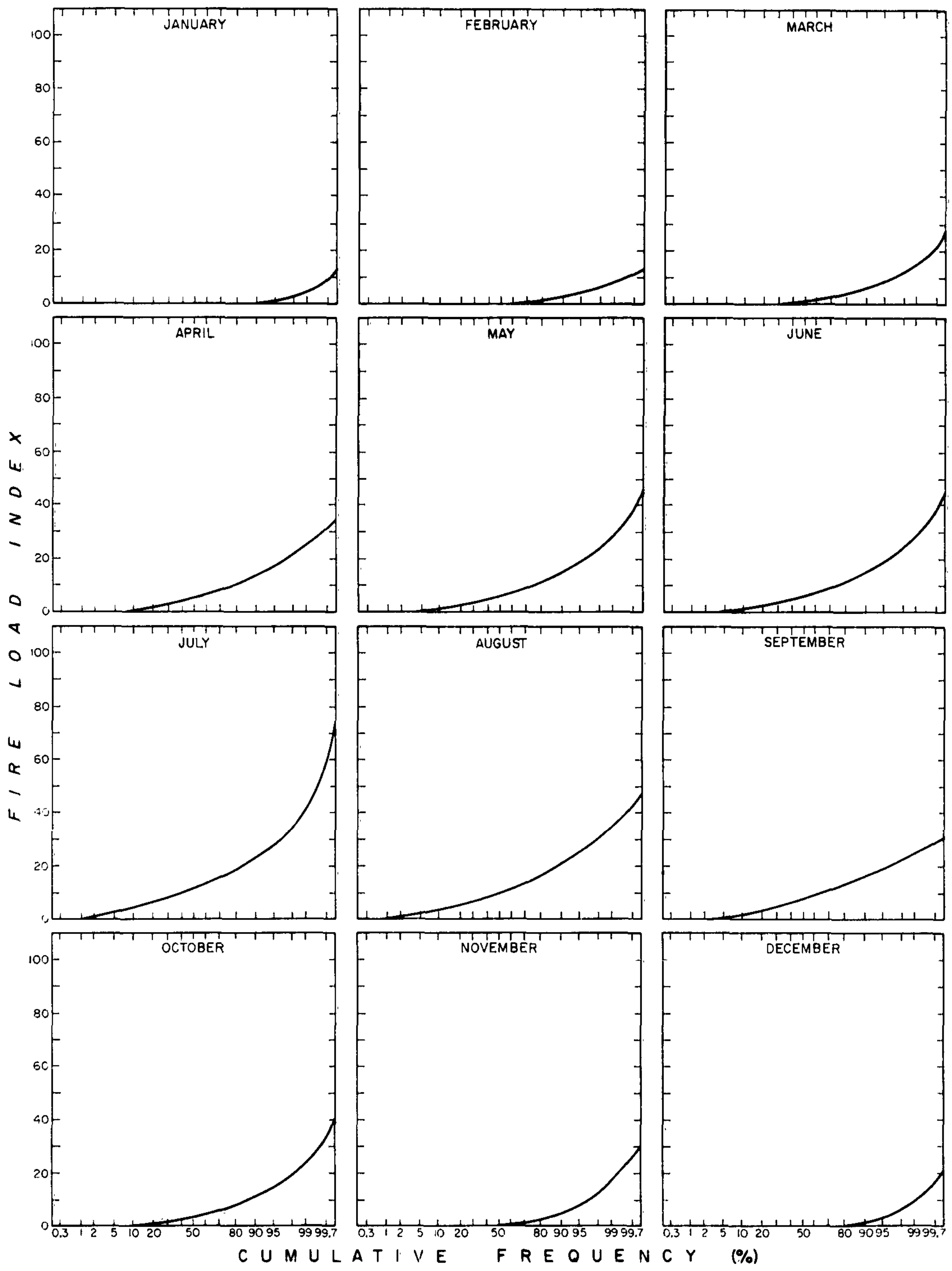
STATION 24138 DILLON, MONTANA



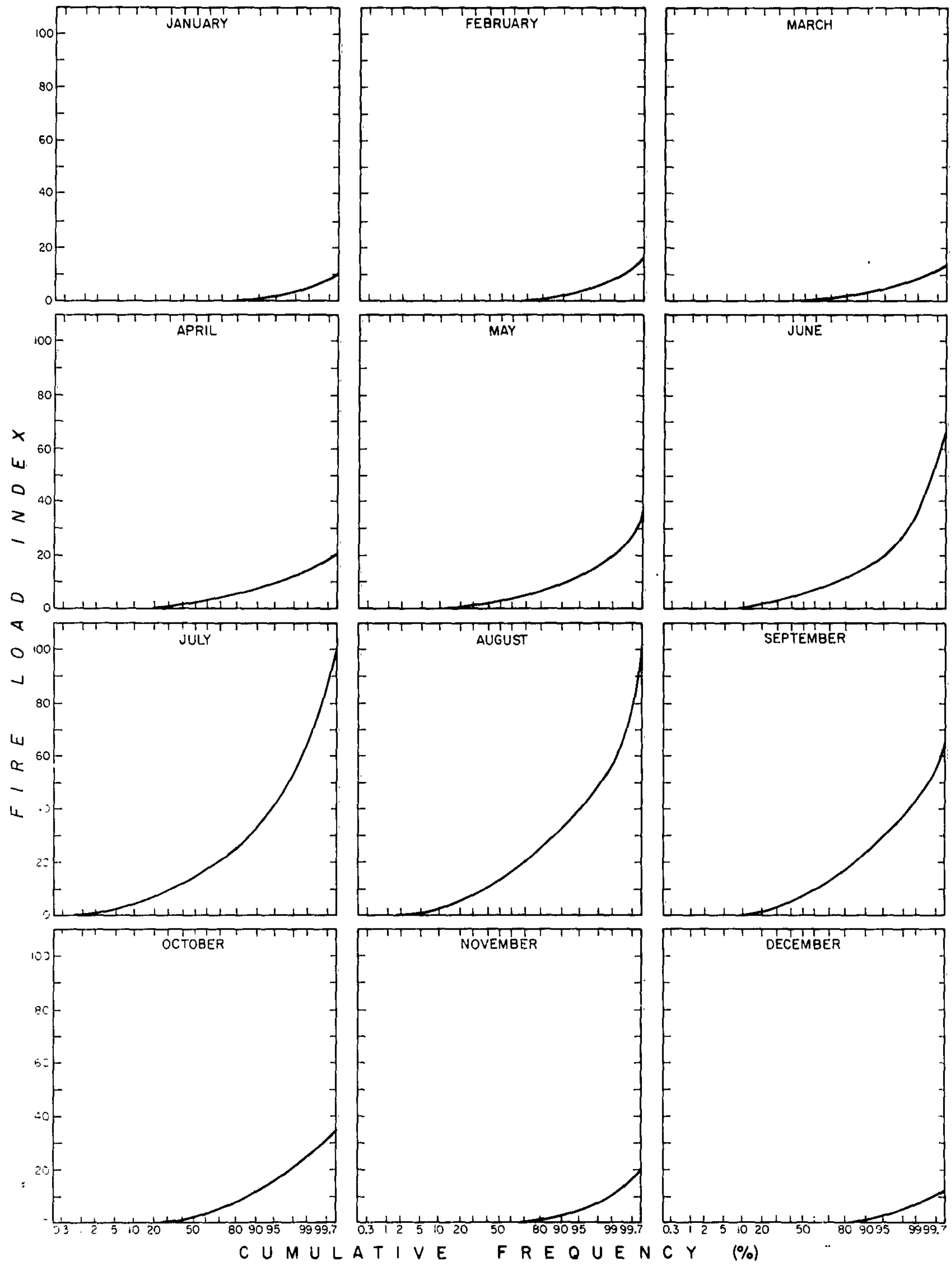
STATION 24157 SPOKANE, WASHINGTON



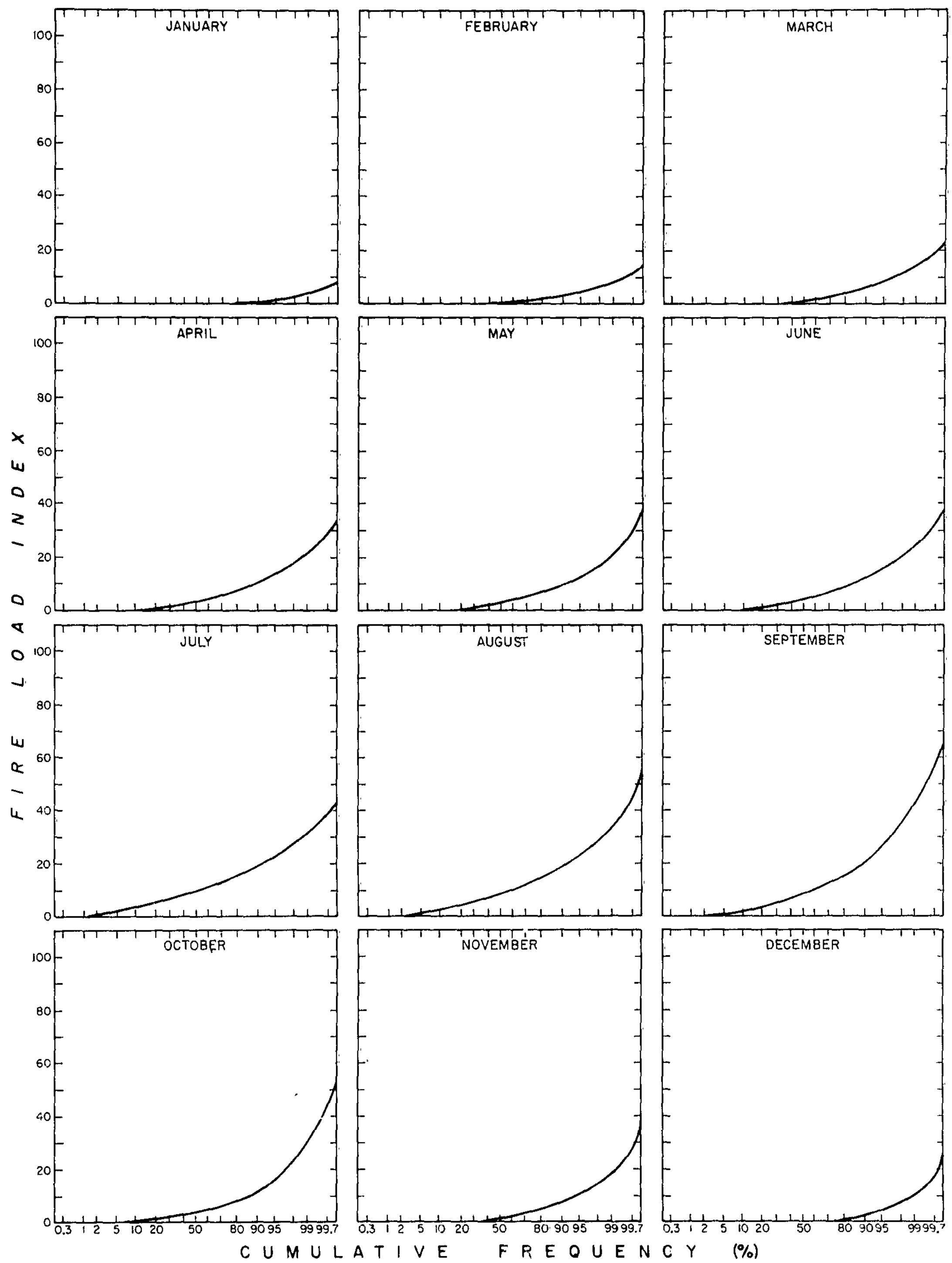
STATION 24243 YAKIMA, WASHINGTON



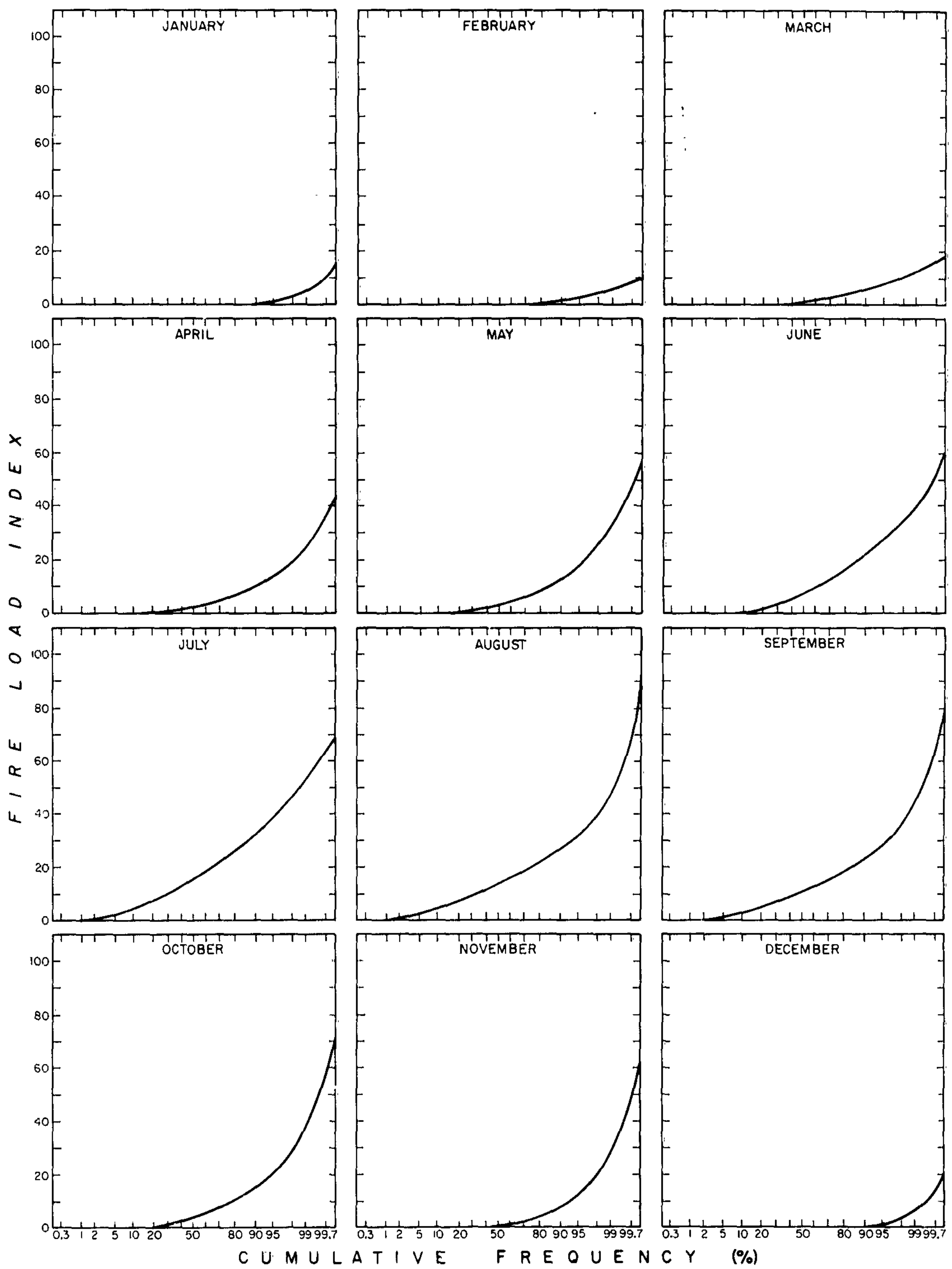
STATION 24155 PENDLETON, OREGON



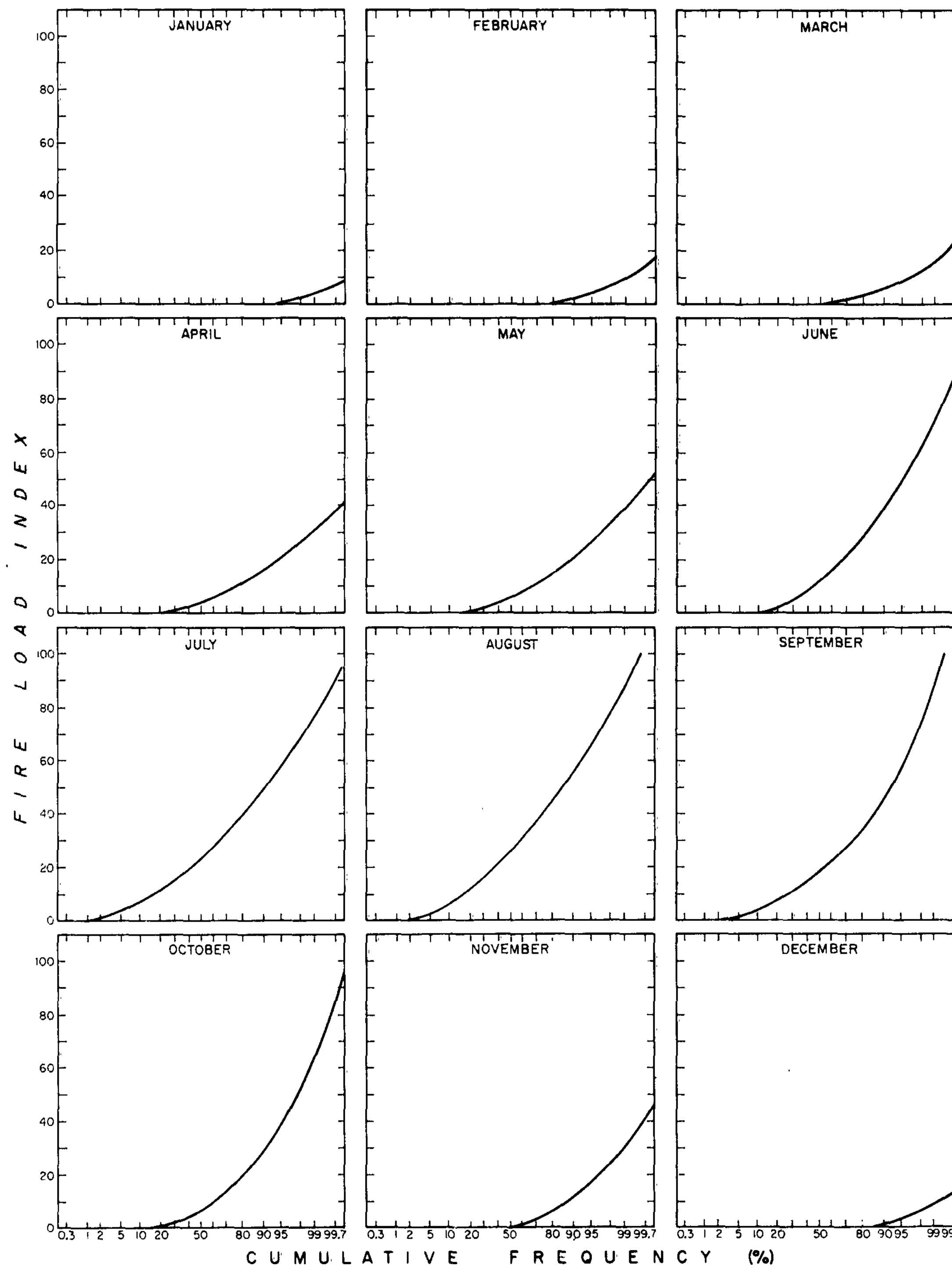
STATION 24230 REDMOND, OREGON



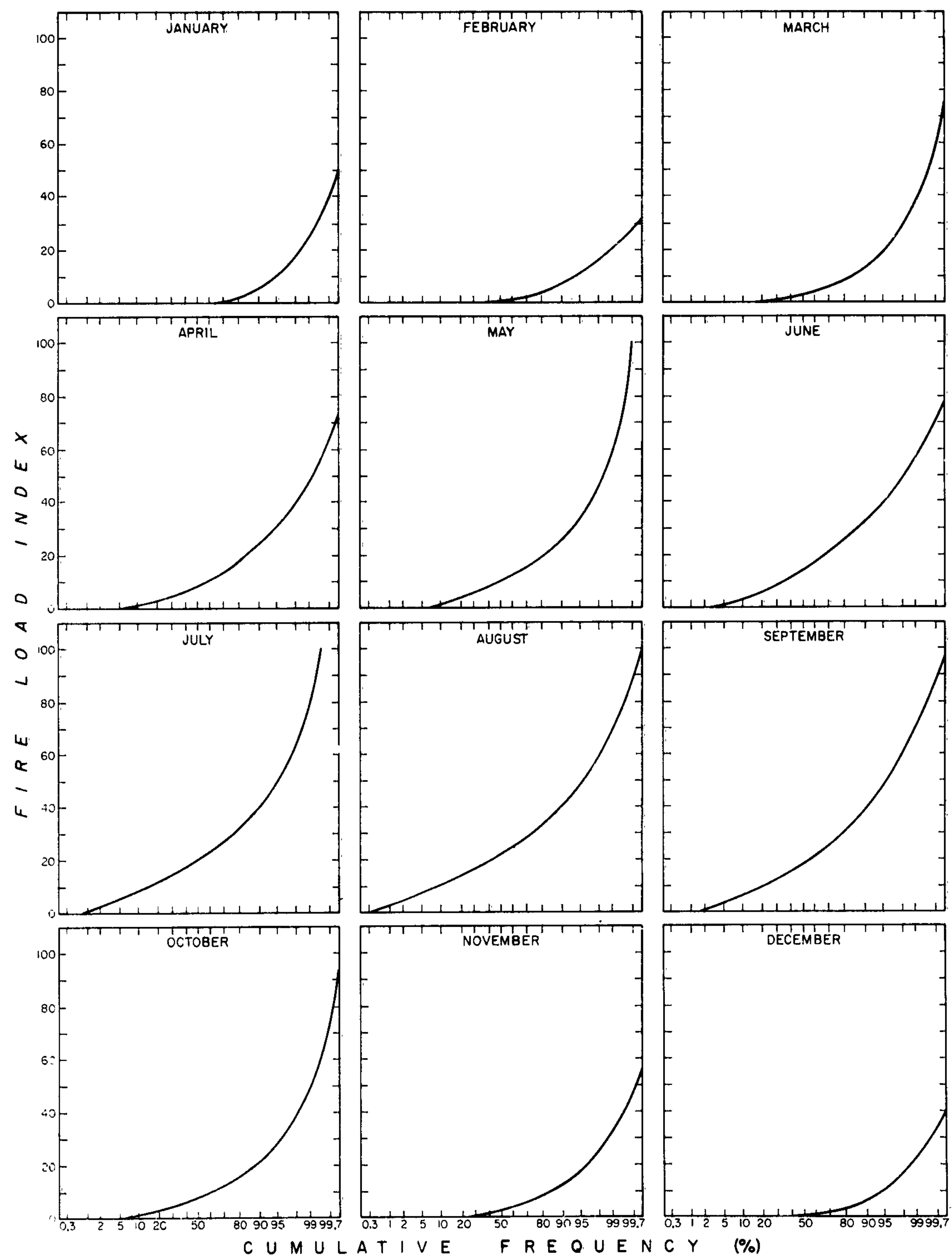
STATION 24131 BOISE, IDAHO



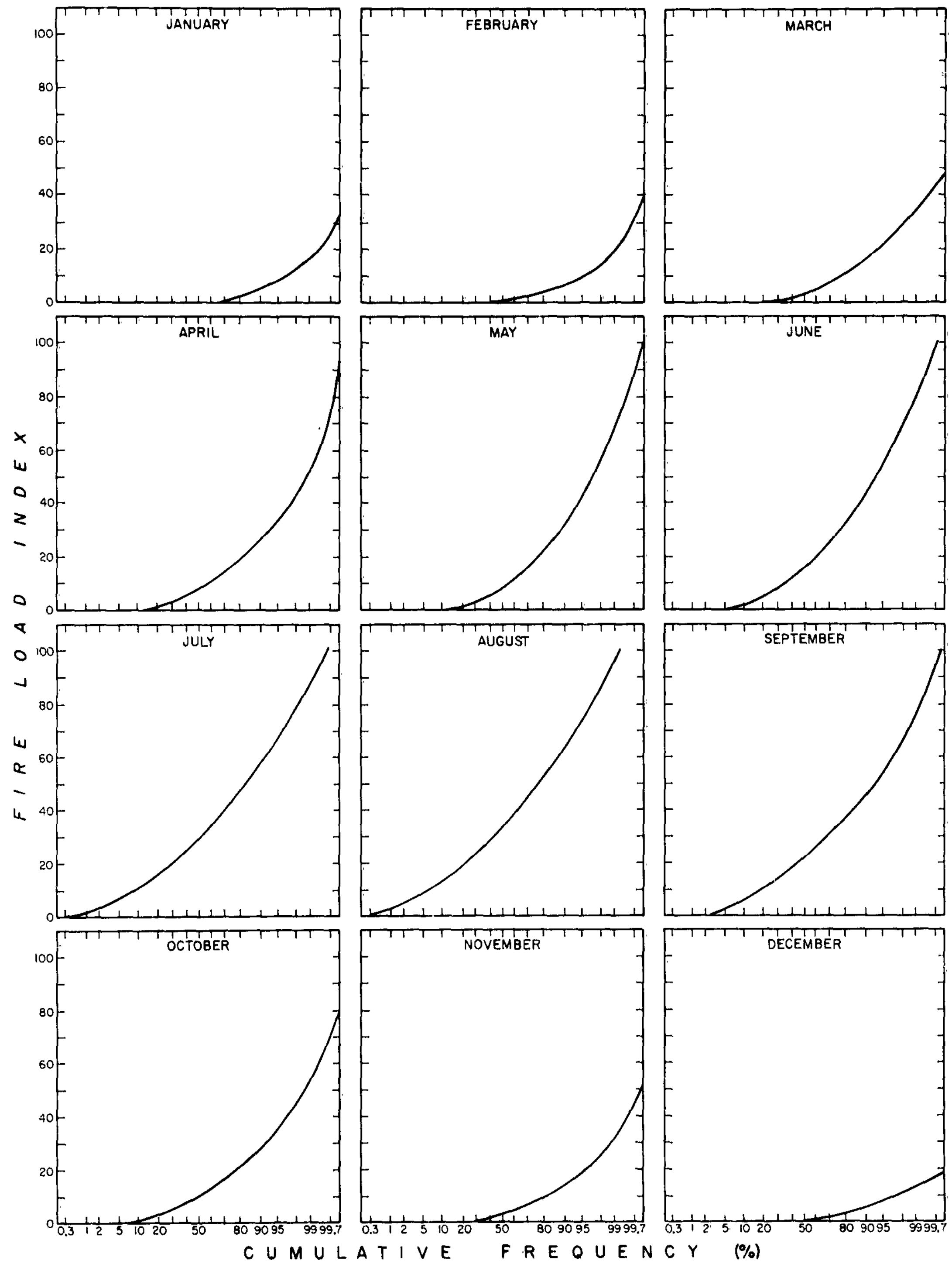
STATION 24156 POCATELLO, IDAHO



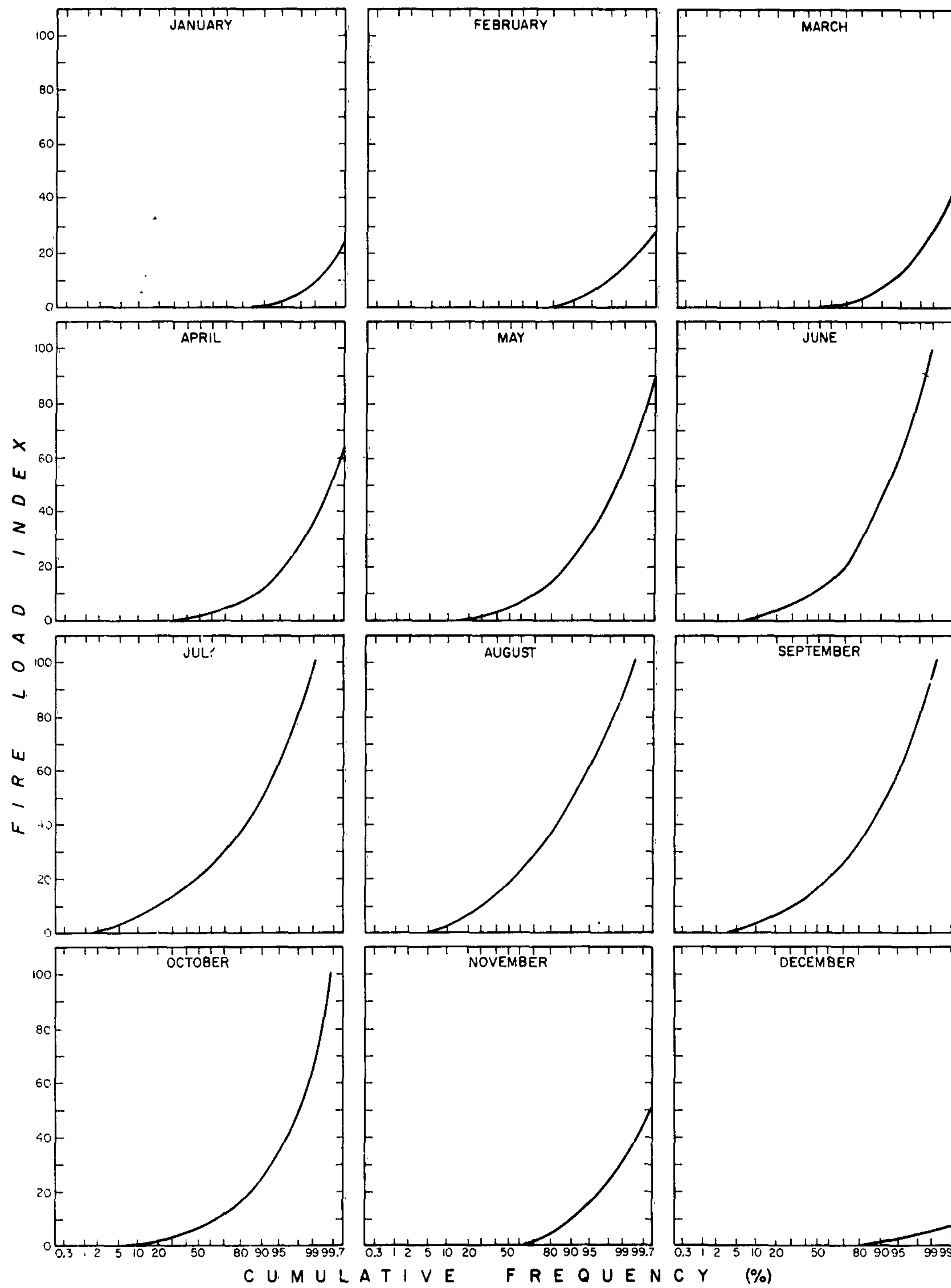
STATION 23185 RENO, NEVADA



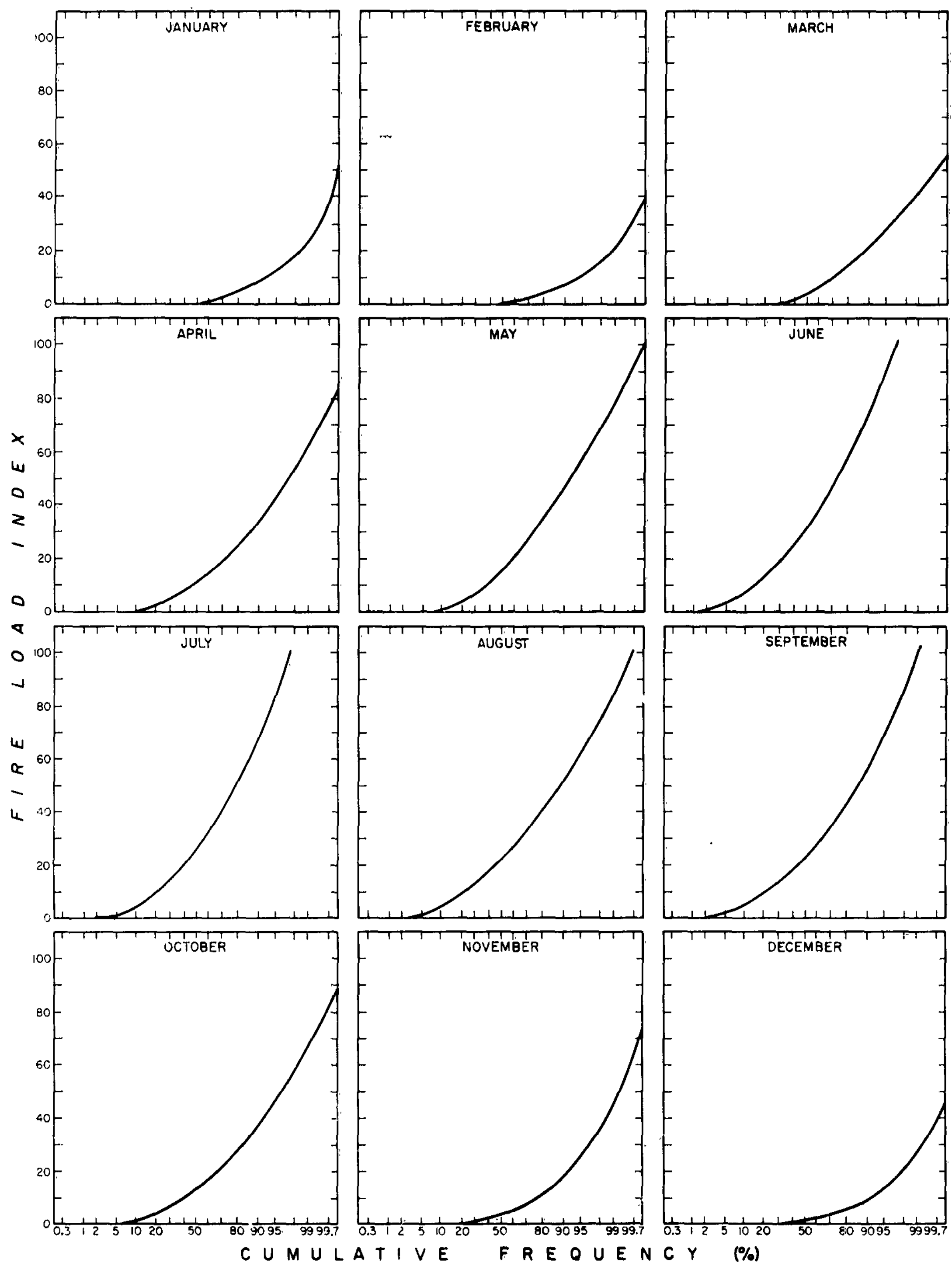
STATION 24128 WINNEMUCCA, NEVADA



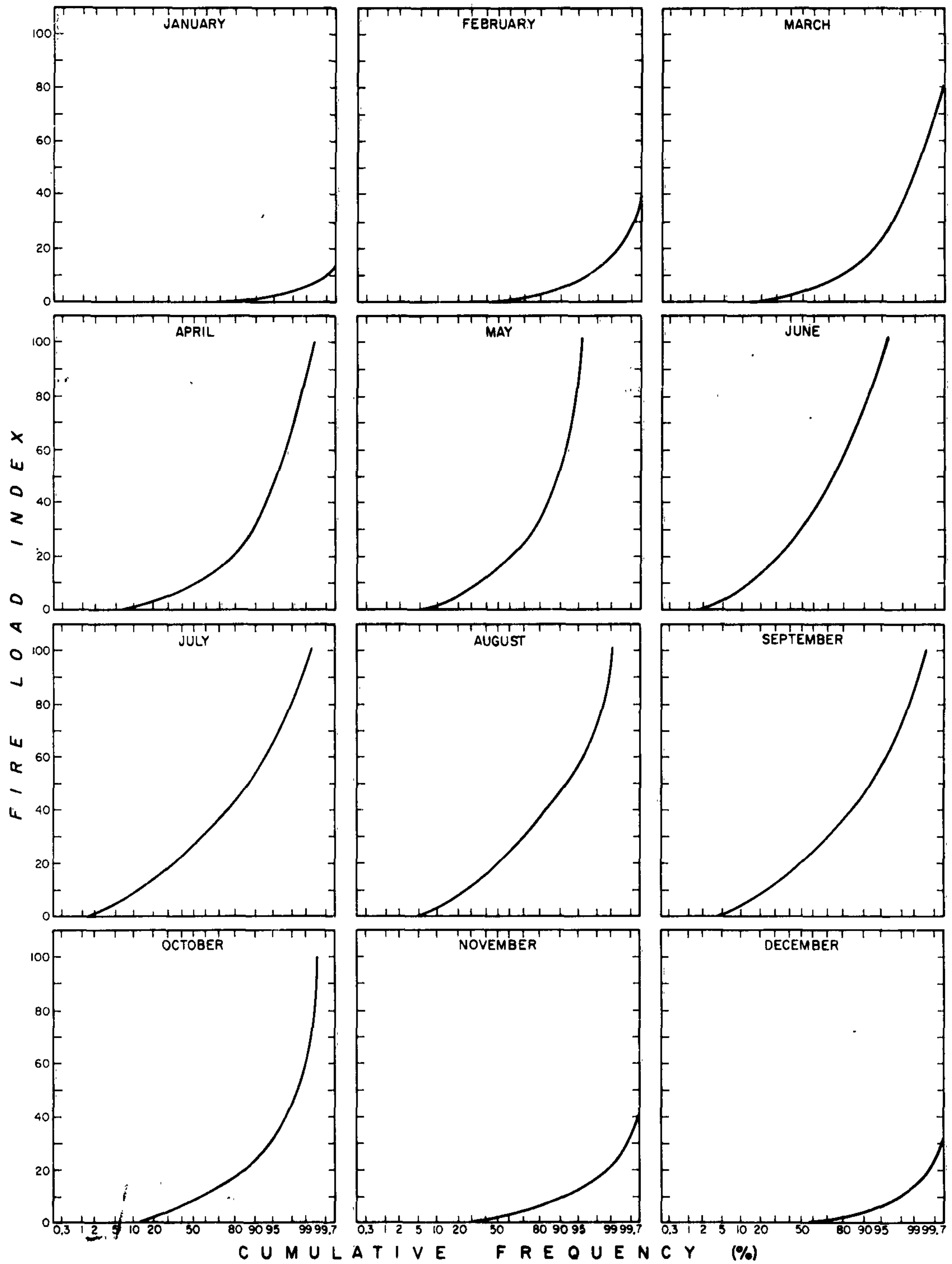
STATION 24127 SALT LAKE CITY, UTAH



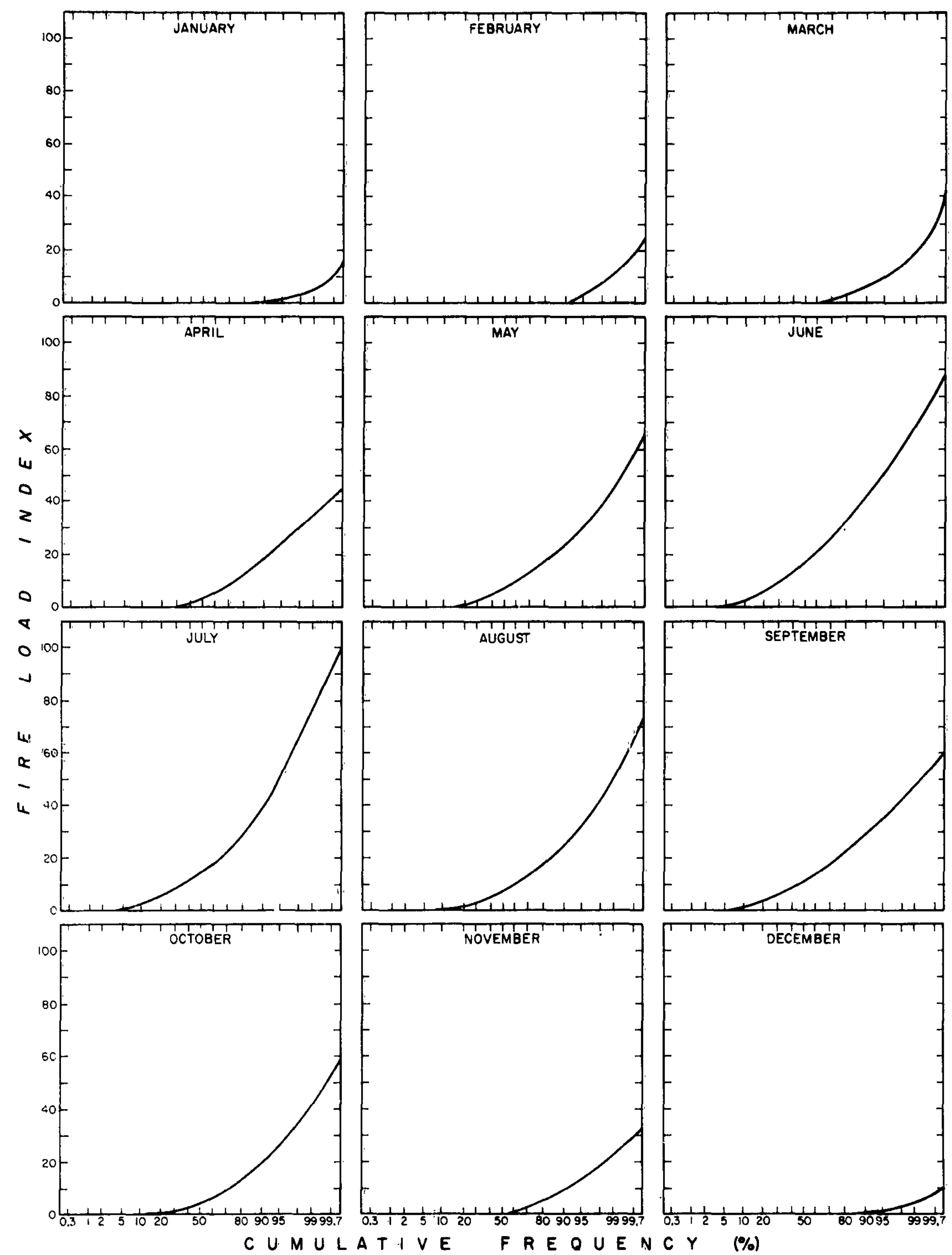
STATION 93129 CEDAR CITY, UTAH



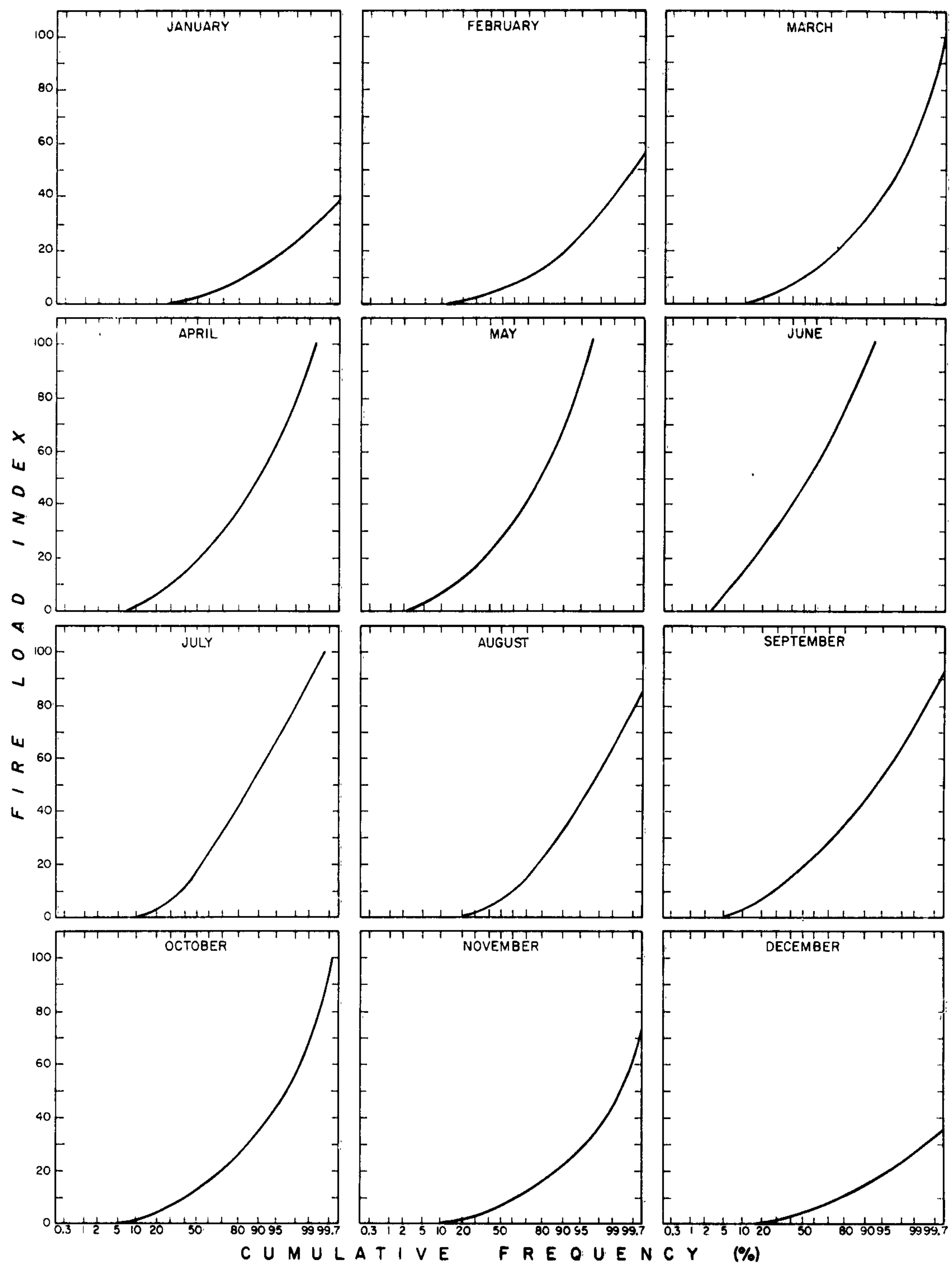
STATION 23066 GRAND JUNCTION, COLORADO



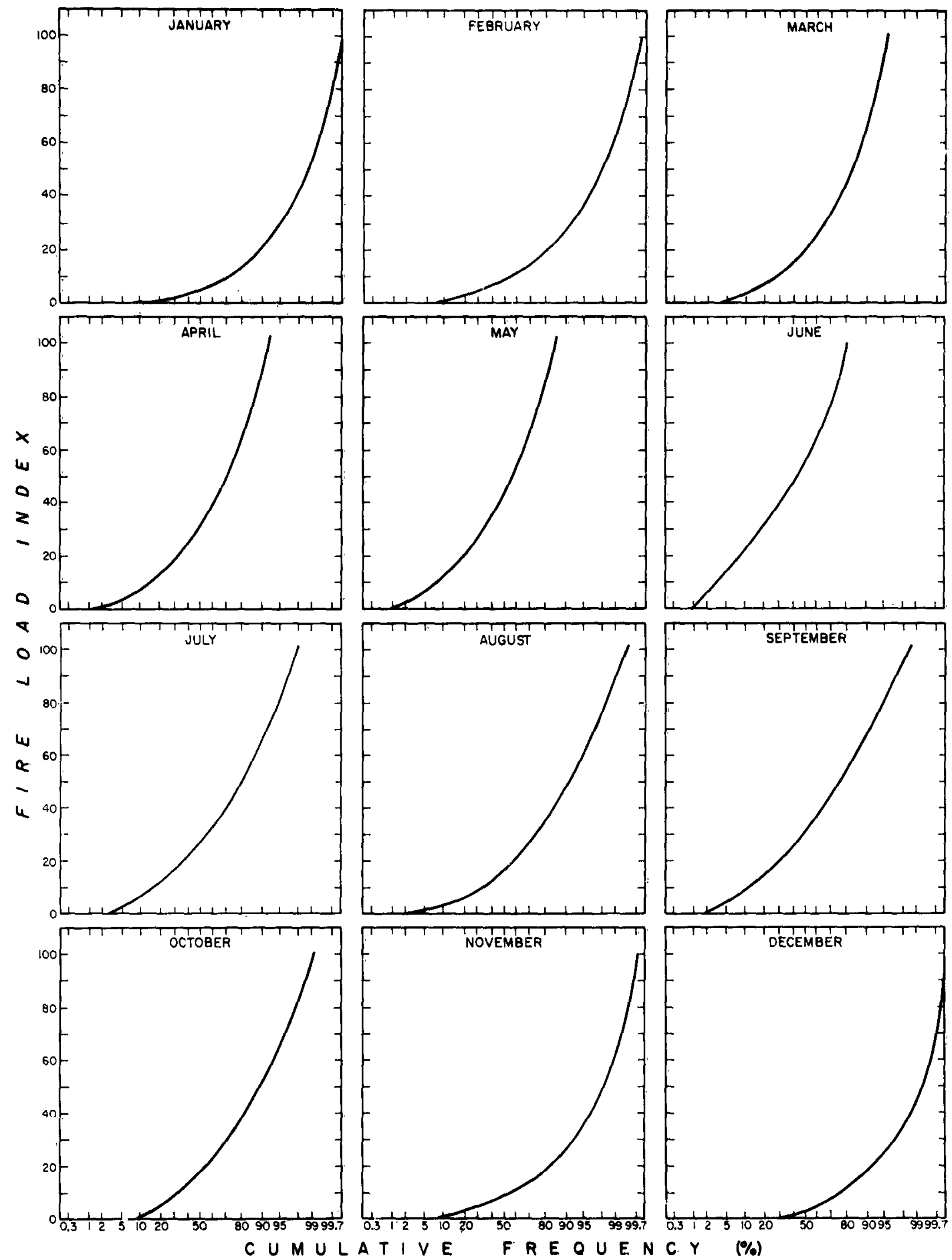
STATION 23063 EAGLE, COLORADO



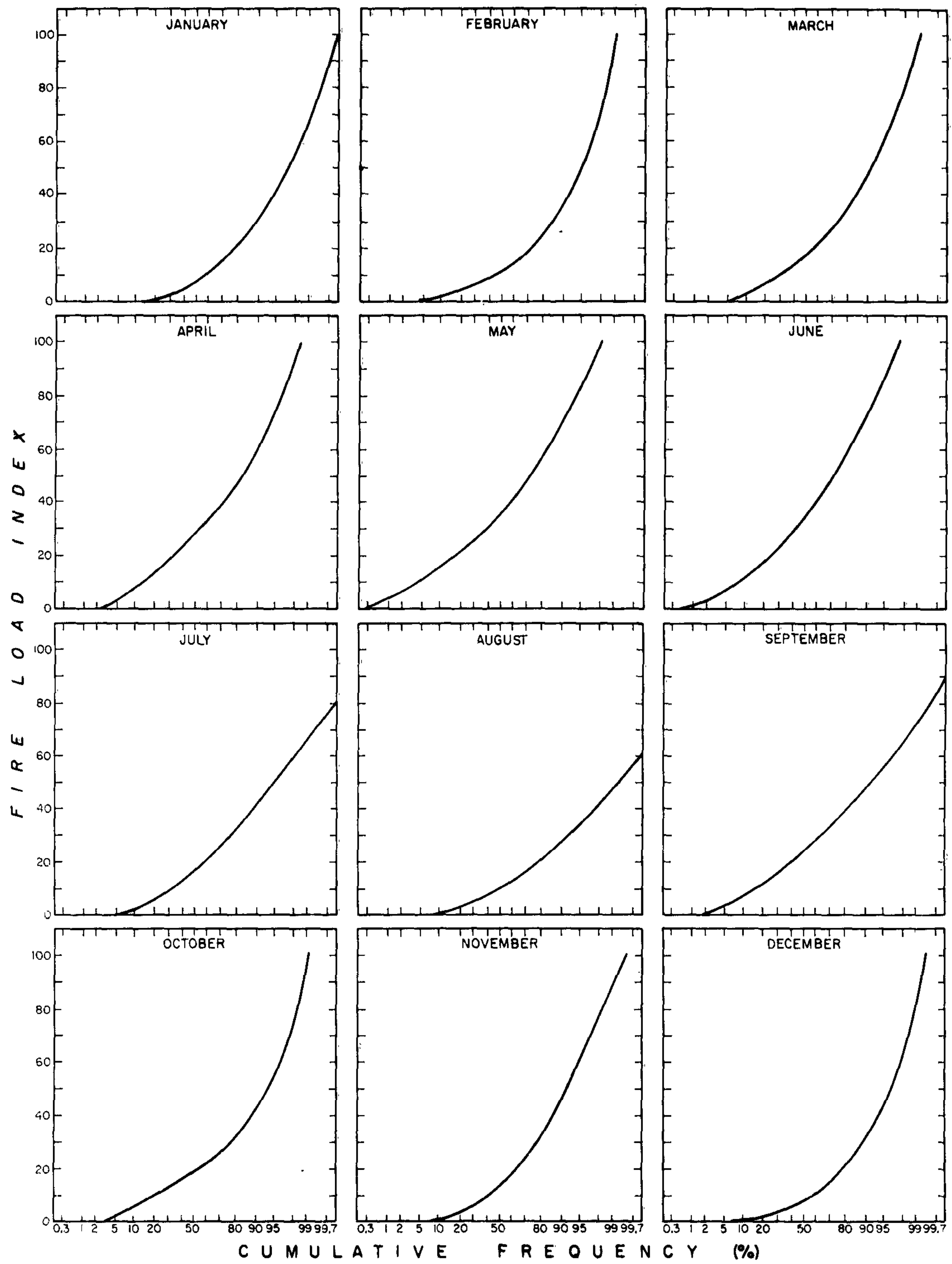
STATION 23184 PRESCOTT, ARIZONA



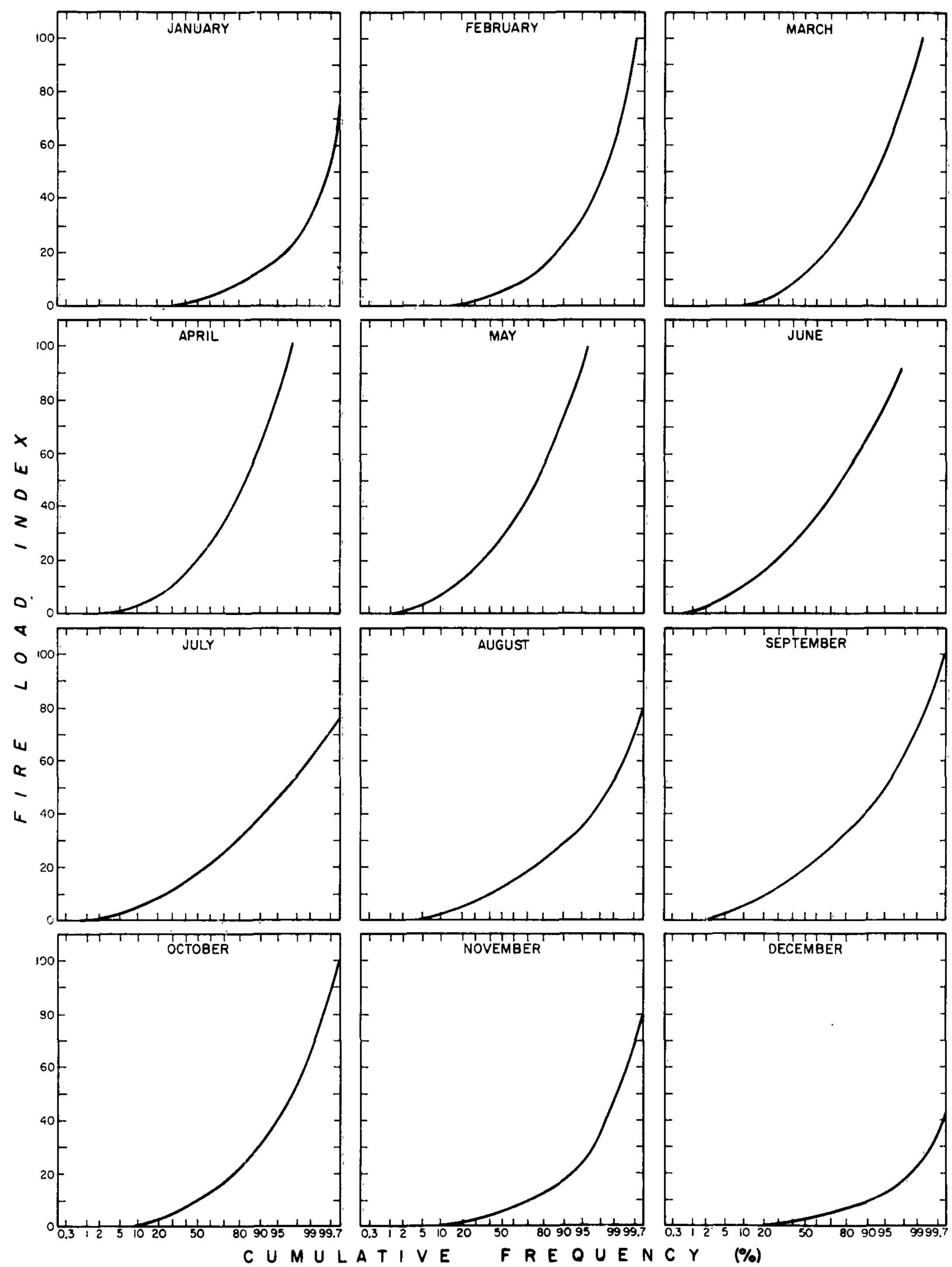
STATION 23194 WINSLOW, ARIZONA



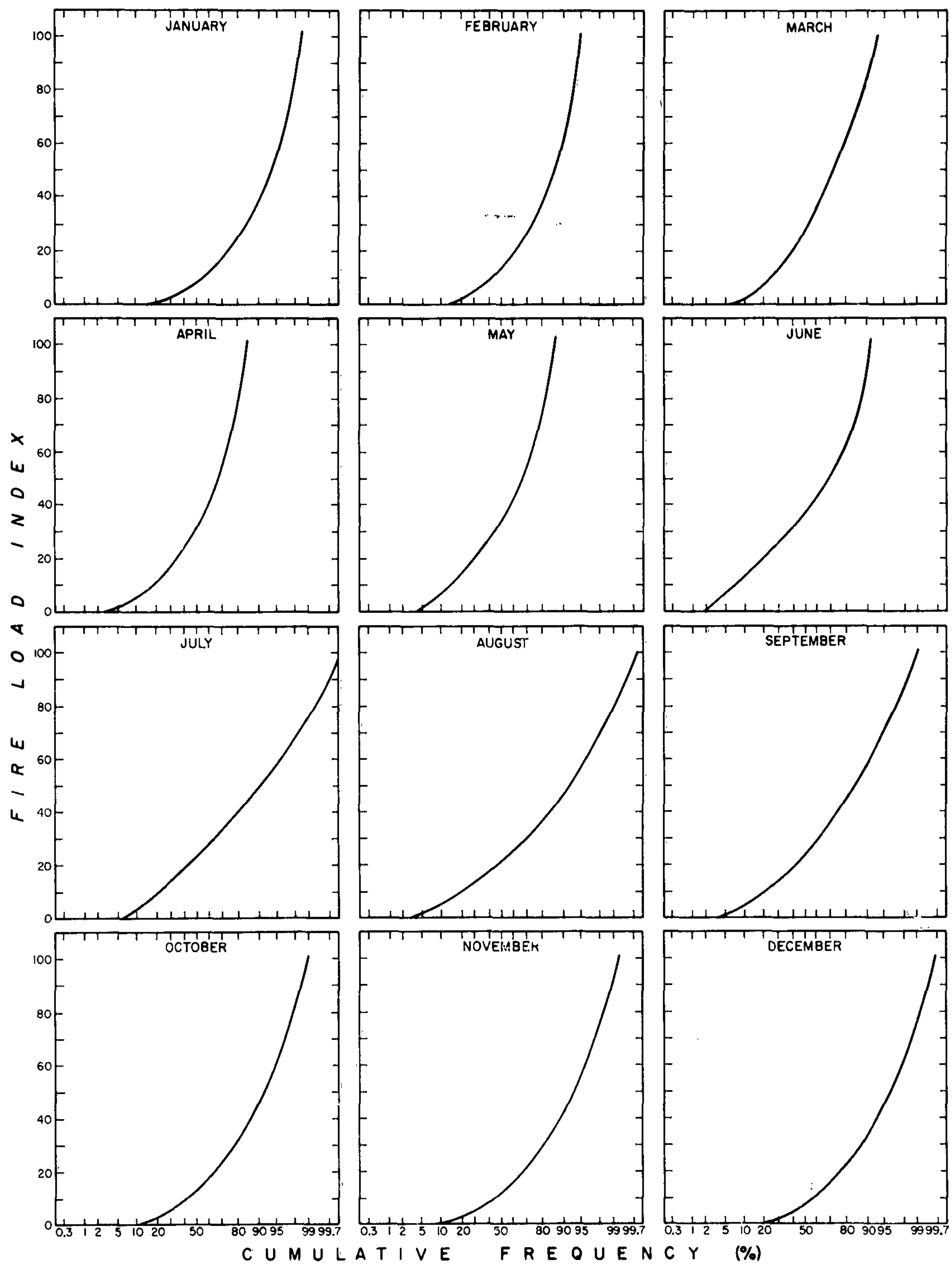
STATION 23160 TUCSON, ARIZONA



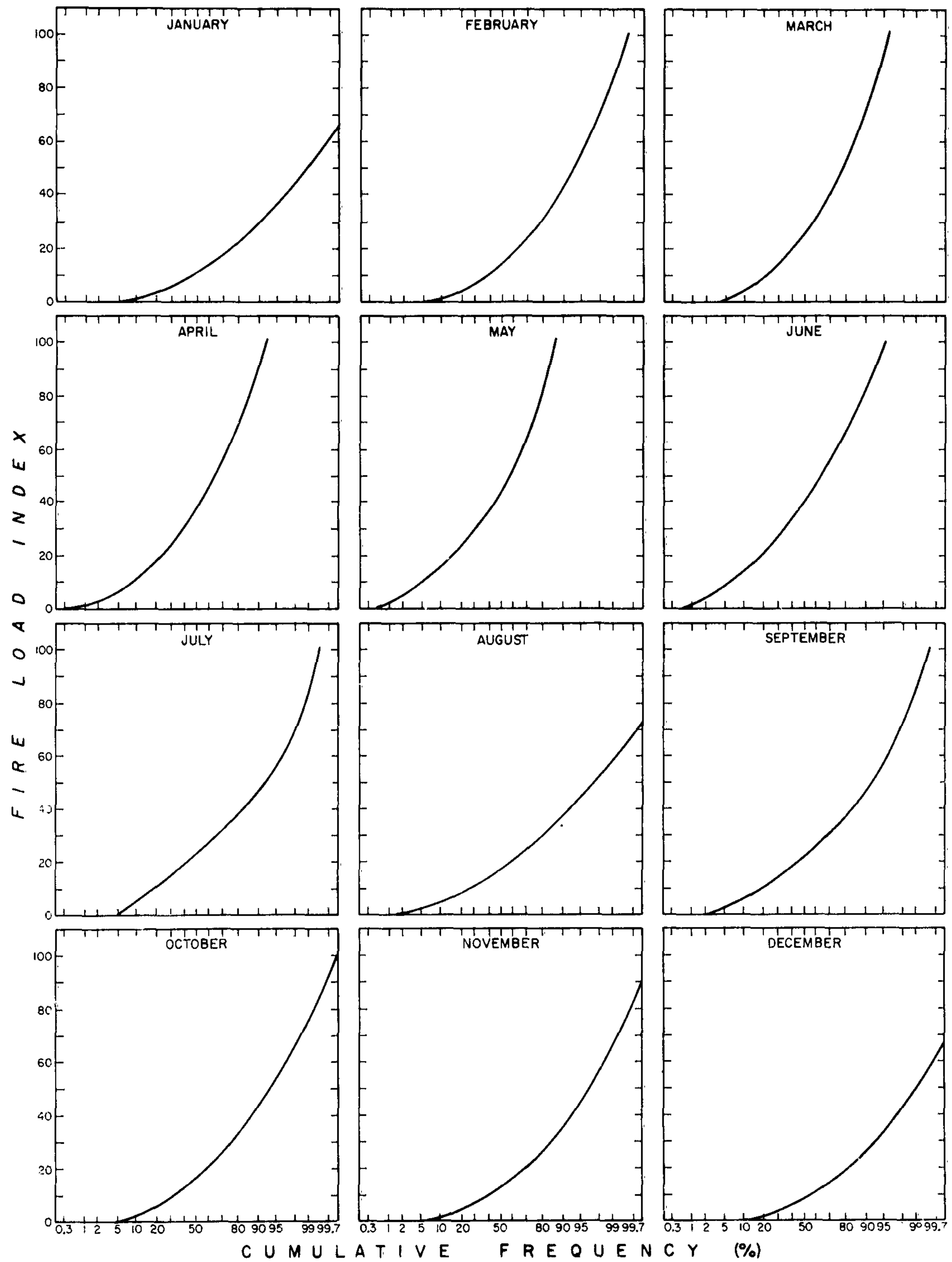
STATION 23050 ALBUQUERQUE, NEW MEXICO



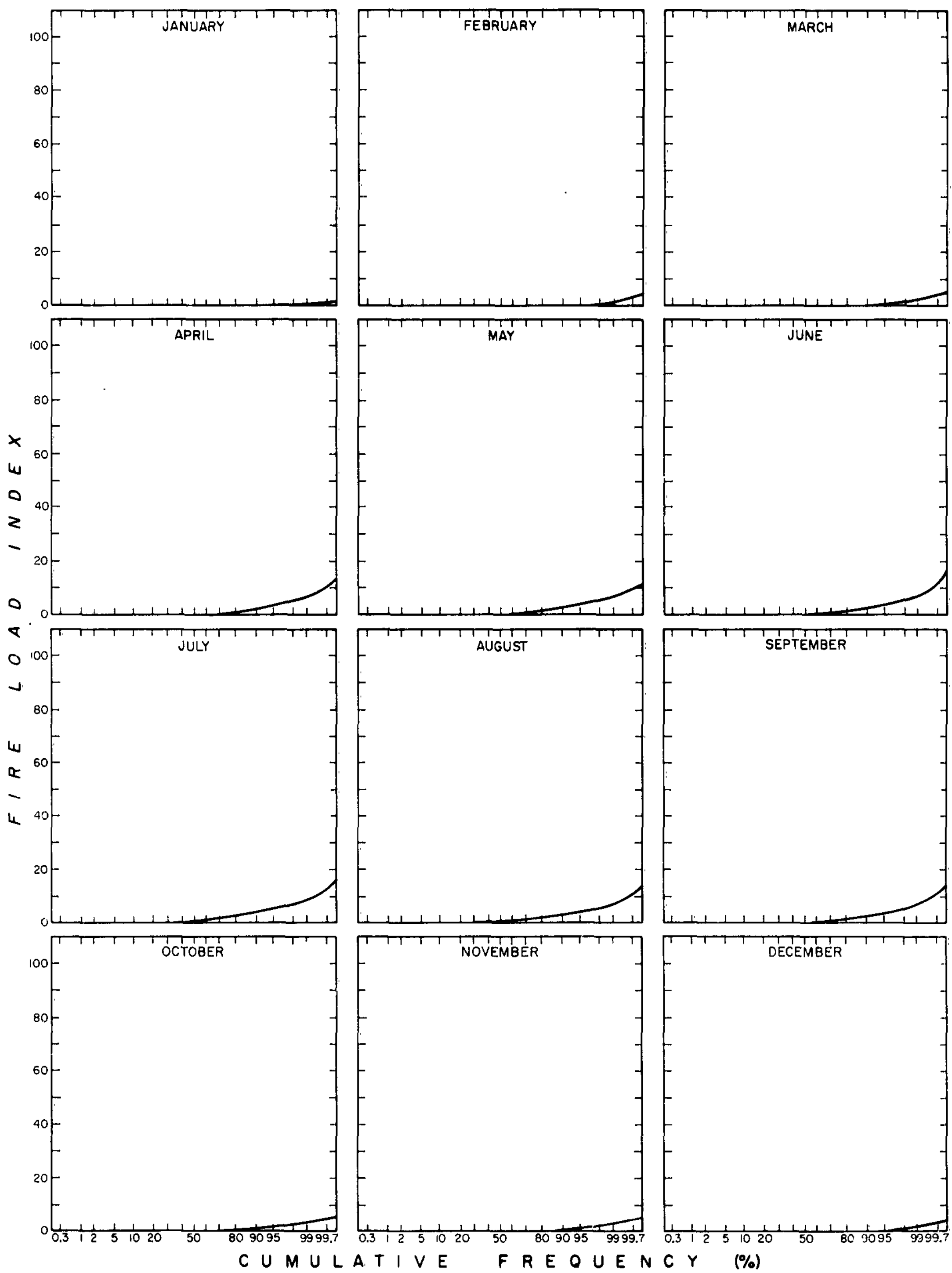
STATION 23043 ROSWELL, NEW MEXICO



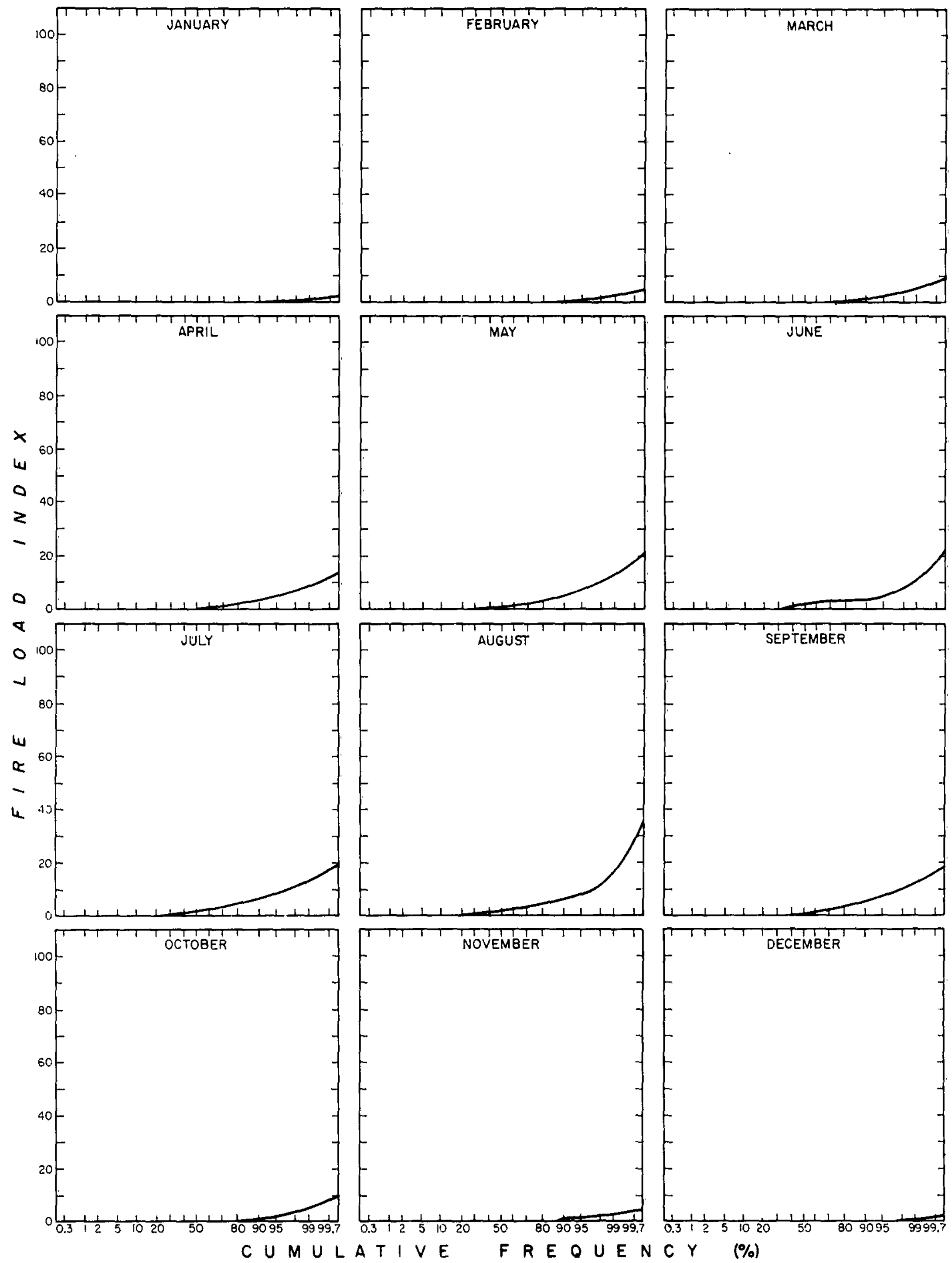
STATION 23044 EL PASO, TEXAS



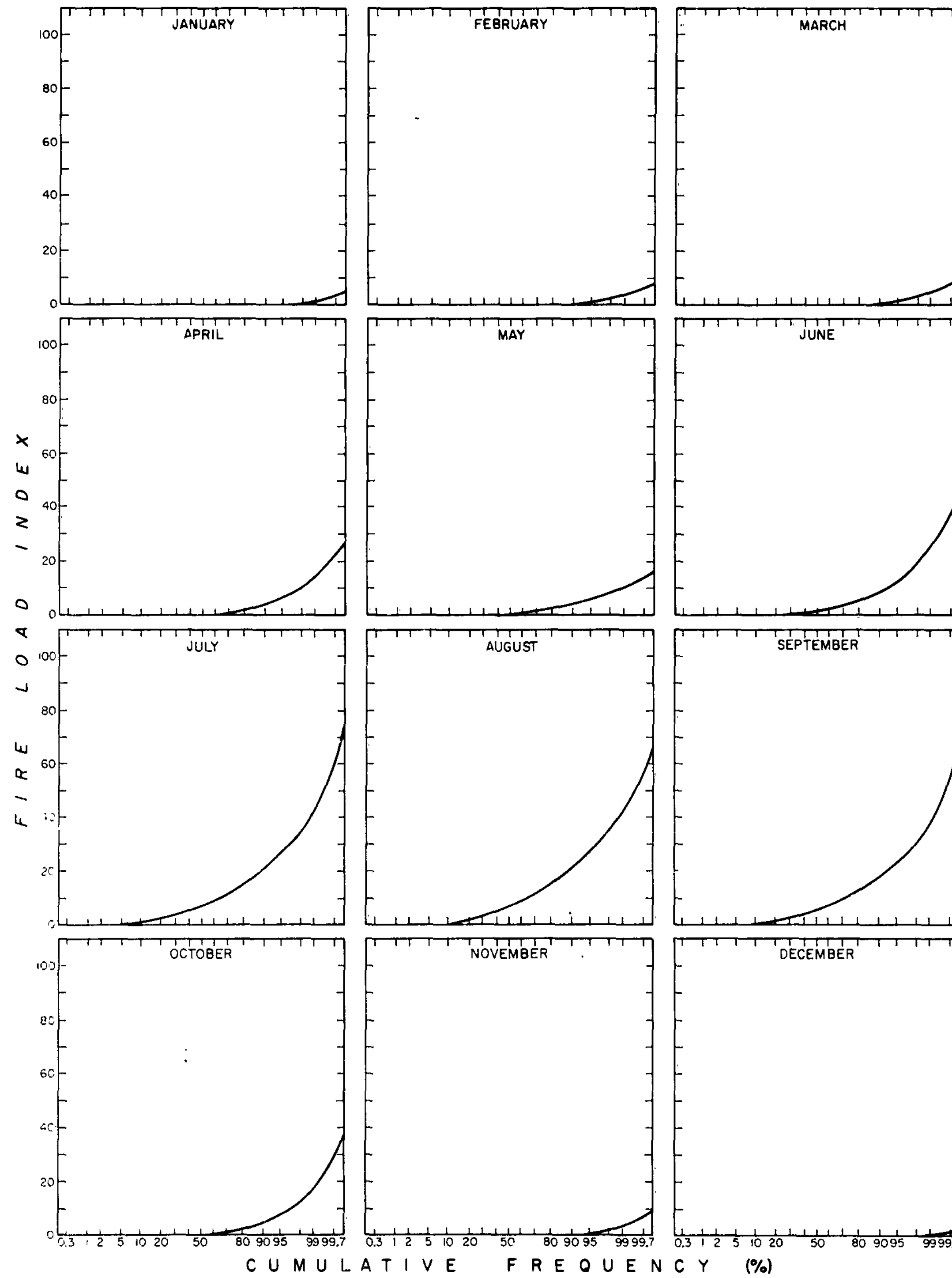
STATION 24244 SEATTLE, WASHINGTON



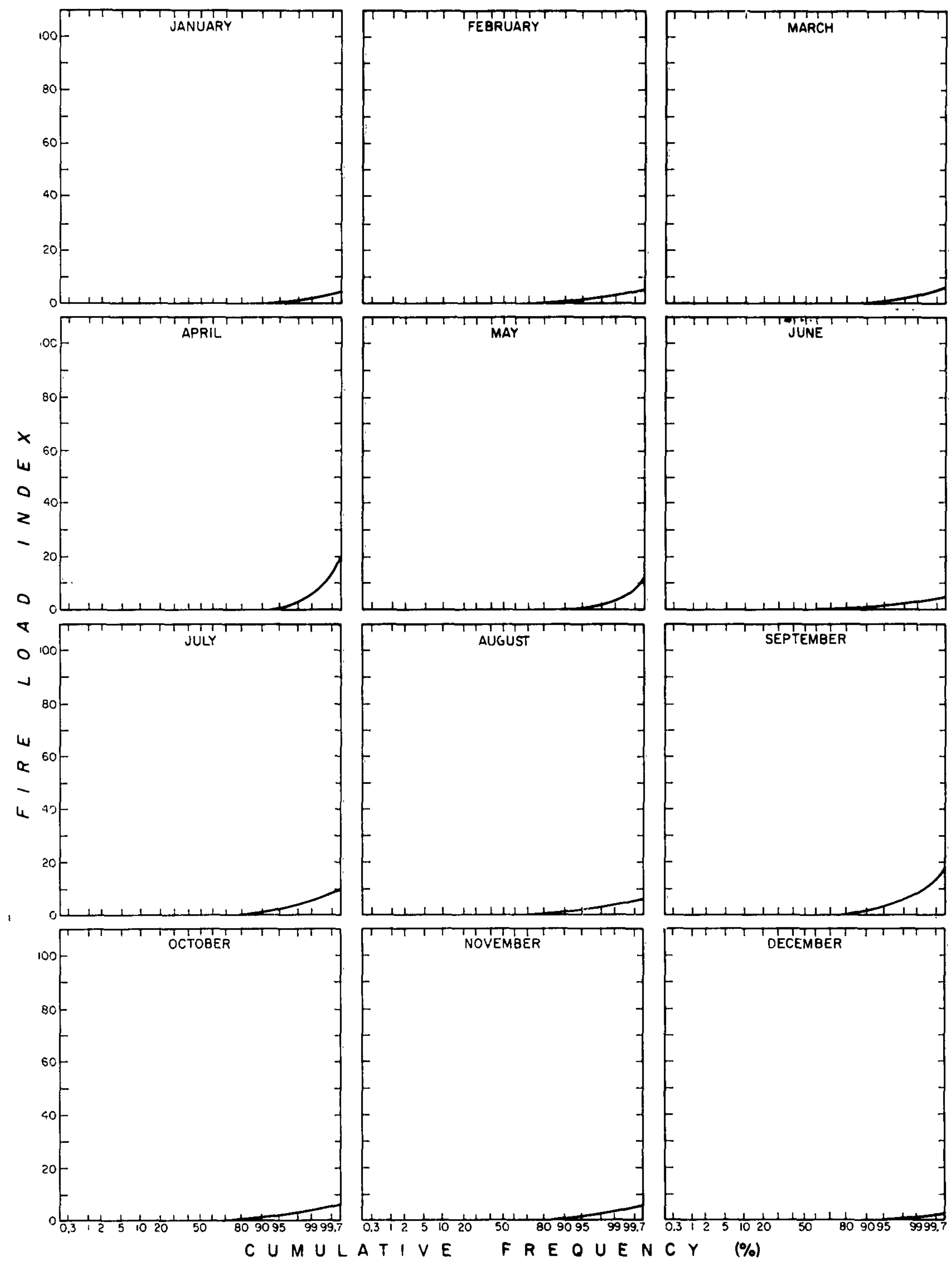
STATION 24227 OLYMPIA, WASHINGTON



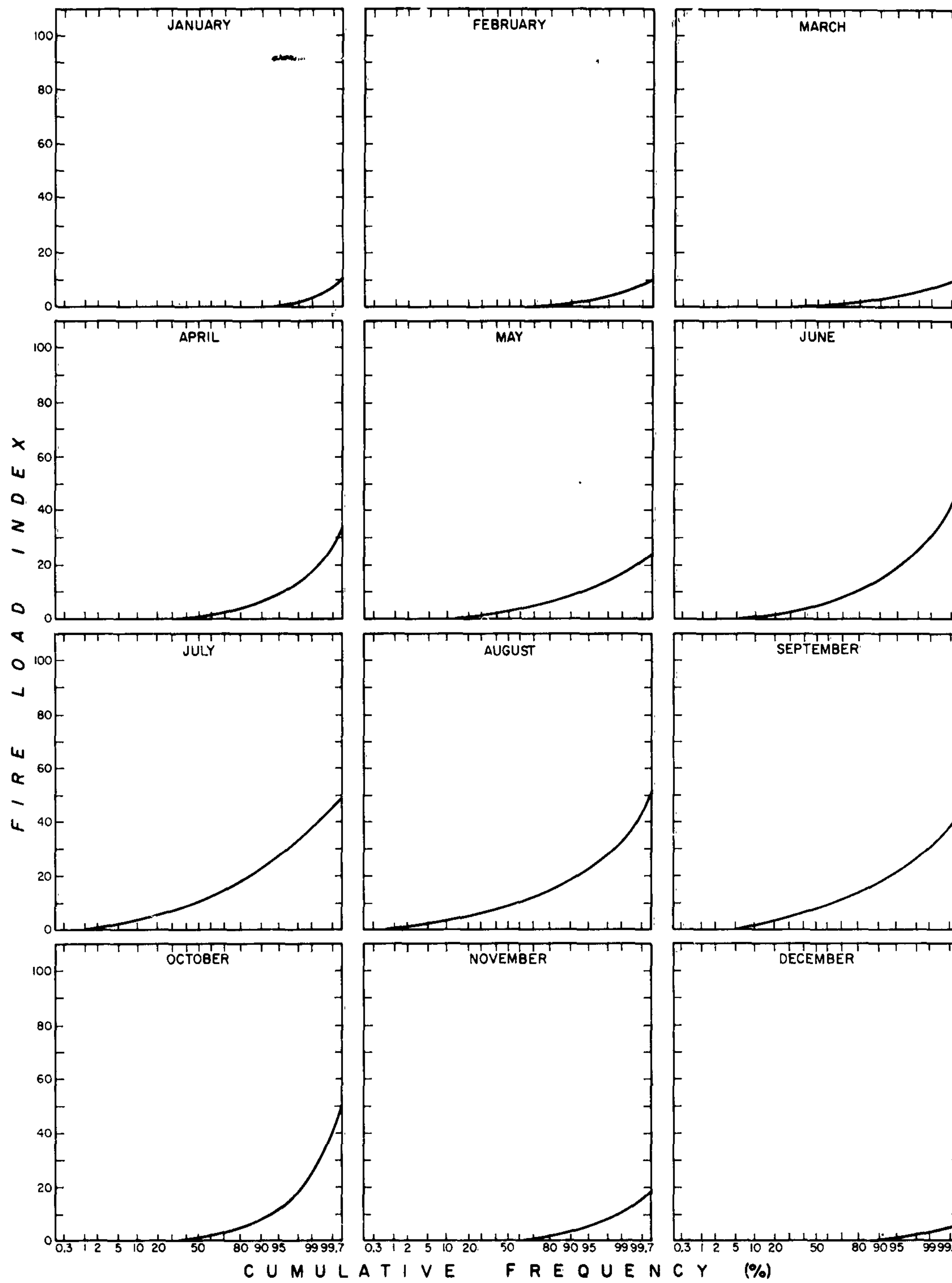
STATION 24221 EUGENE, OREGON



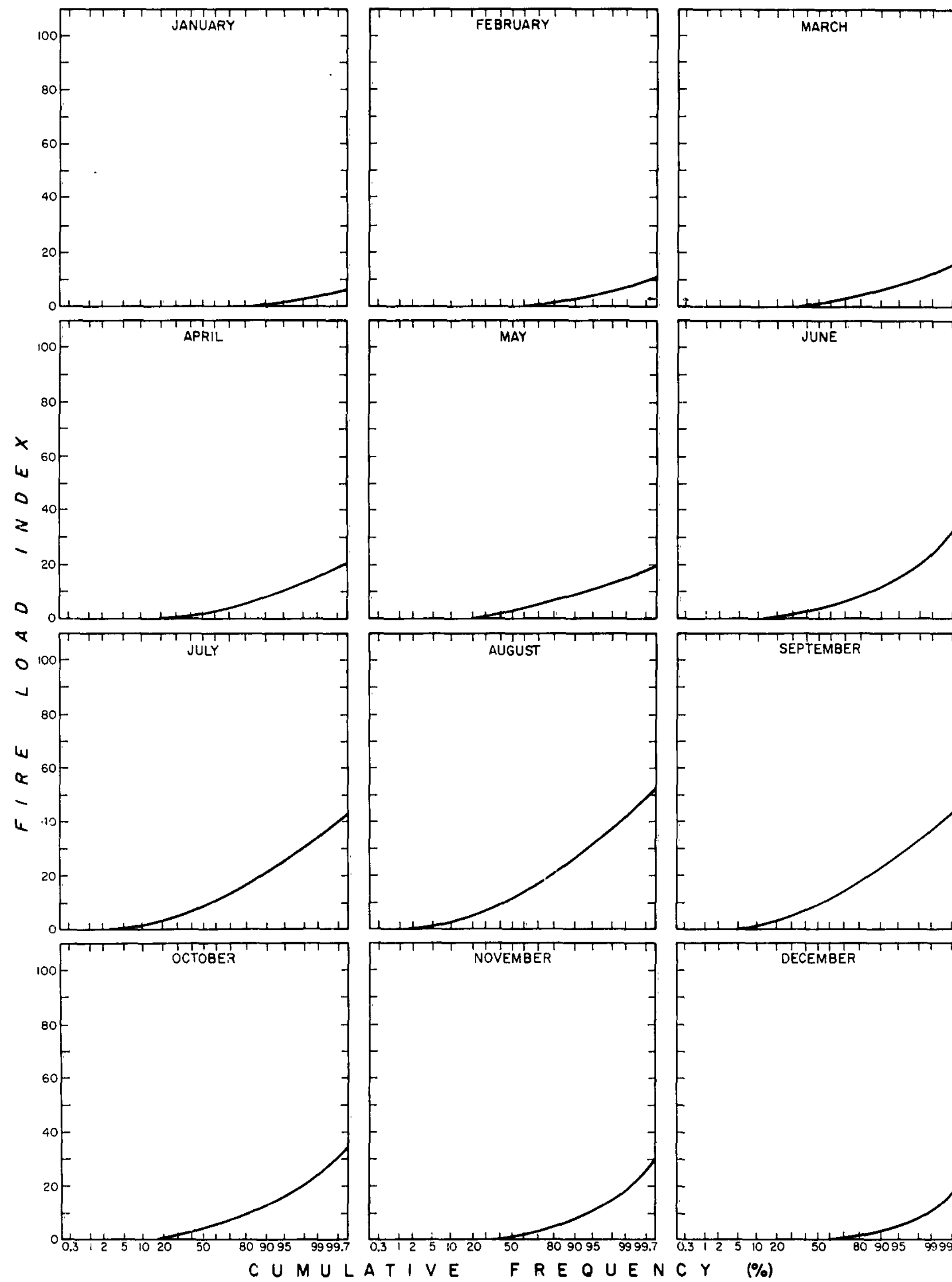
STATION 24284 NORTH BEND, OREGON



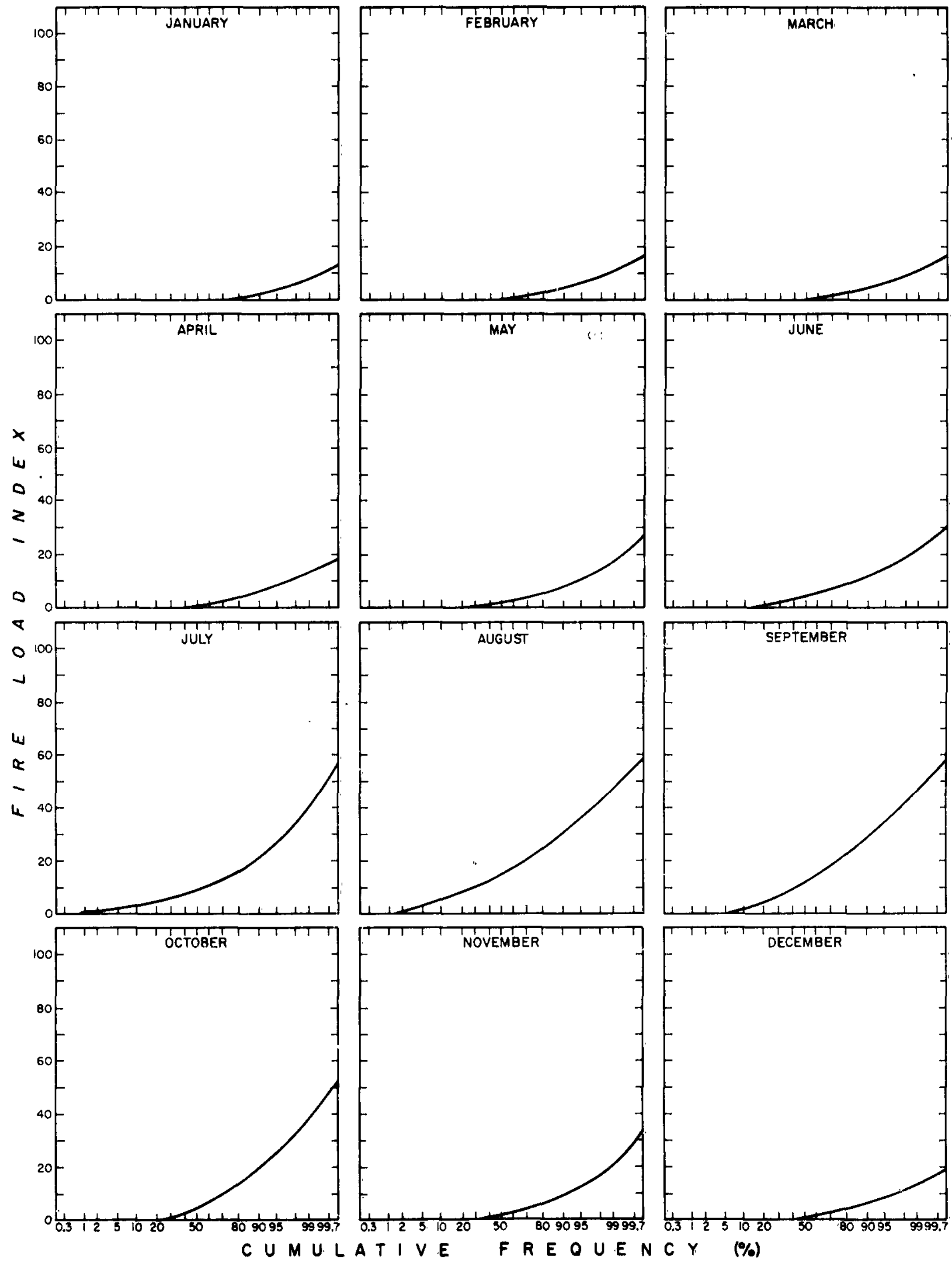
STATION 24225 MEDFORD, OREGON



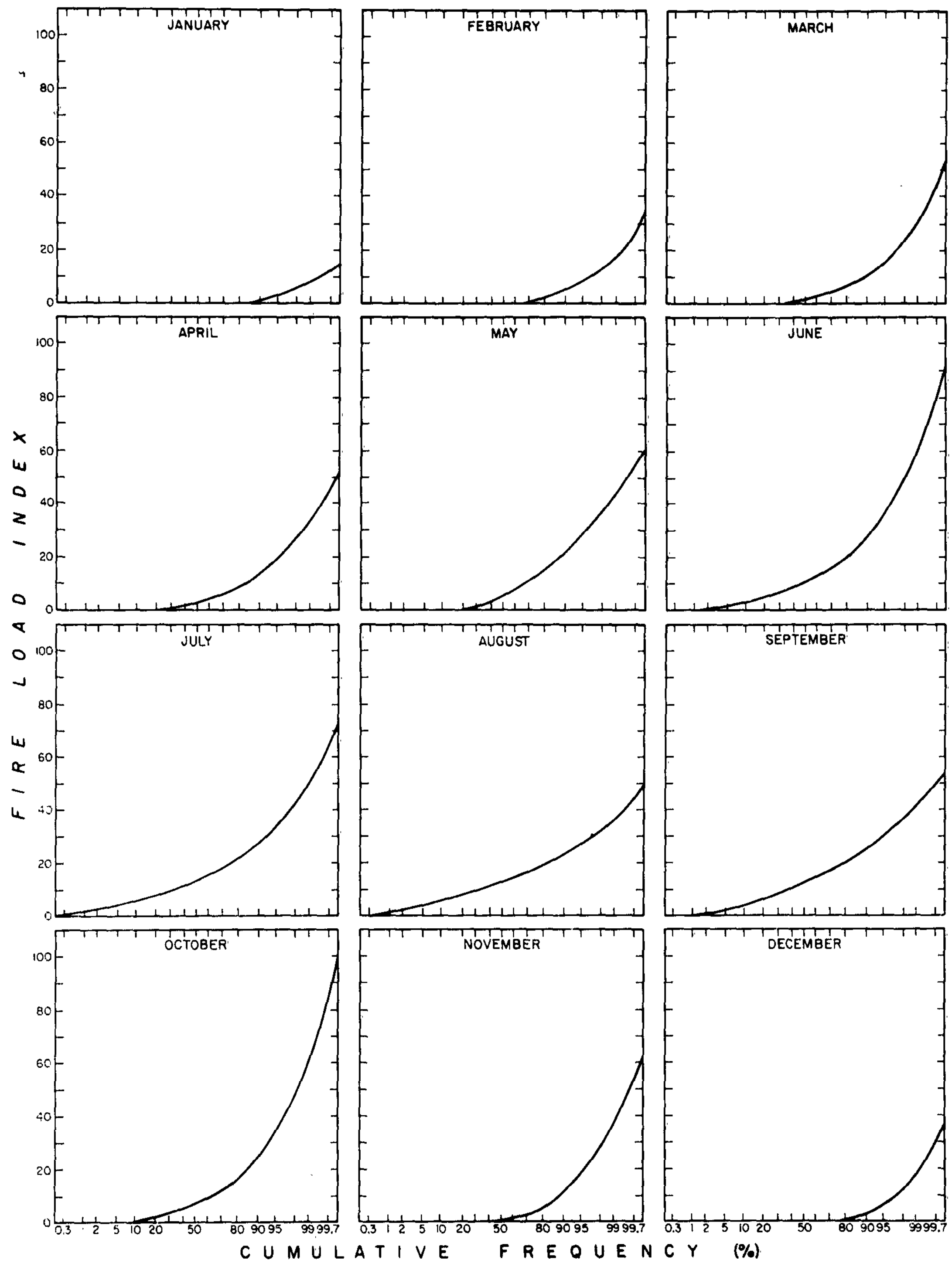
STATION 24215 MT. SHASTA, CALIFORNIA



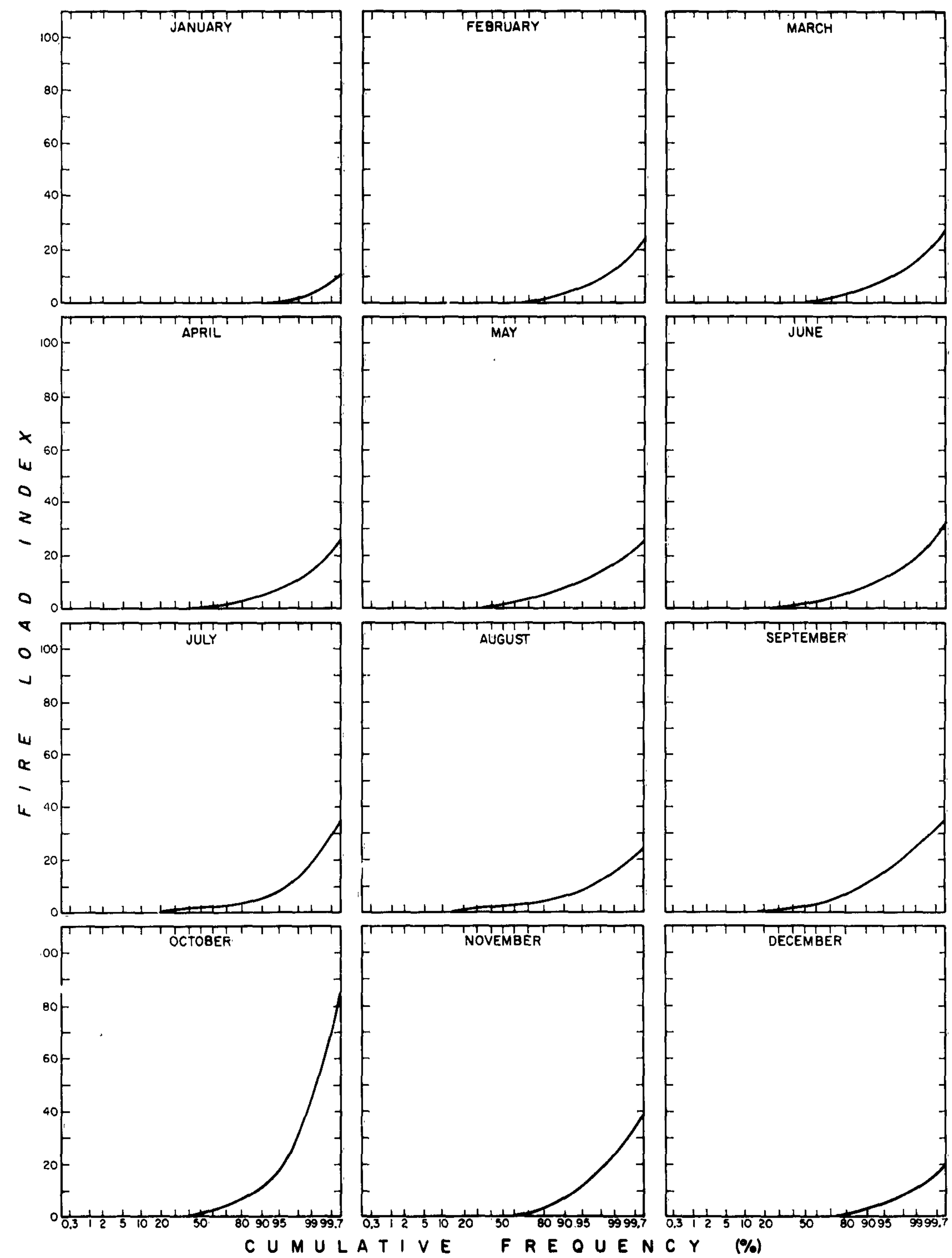
STATION 23225 BLUE CANYON, CALIFORNIA



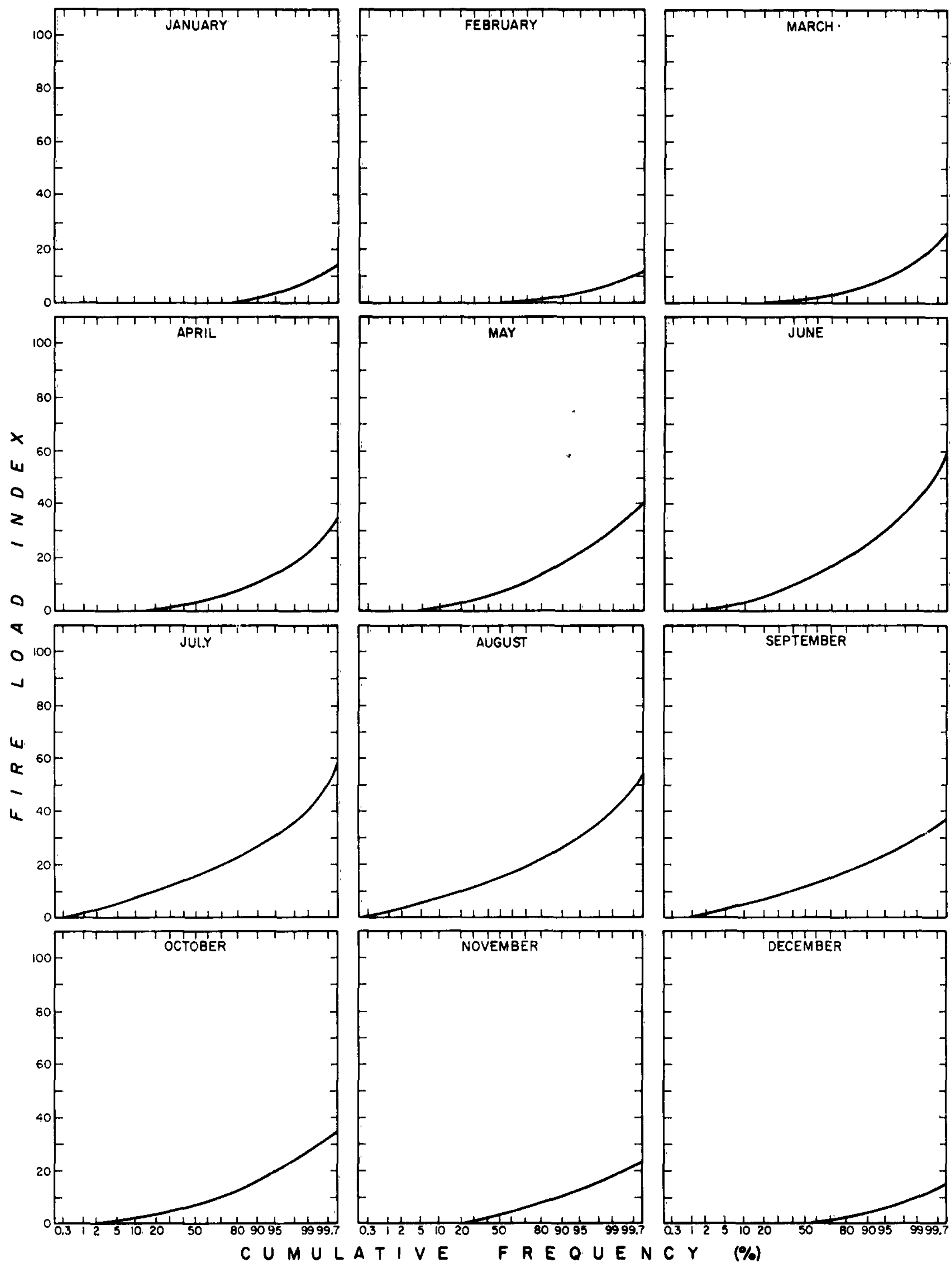
STATION 23232 SACRAMENTO, CALIFORNIA



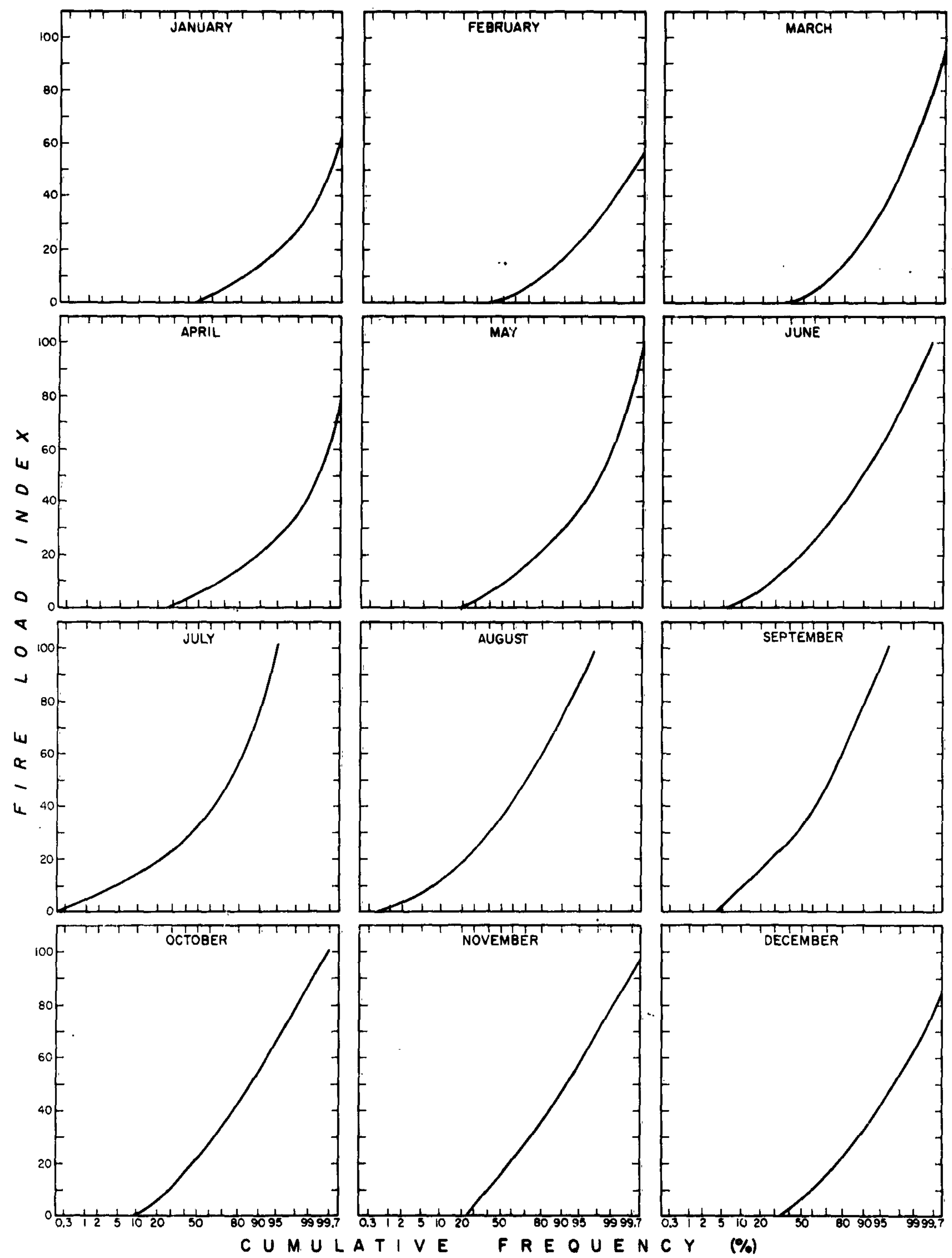
STATION 23230 OAKLAND, CALIFORNIA



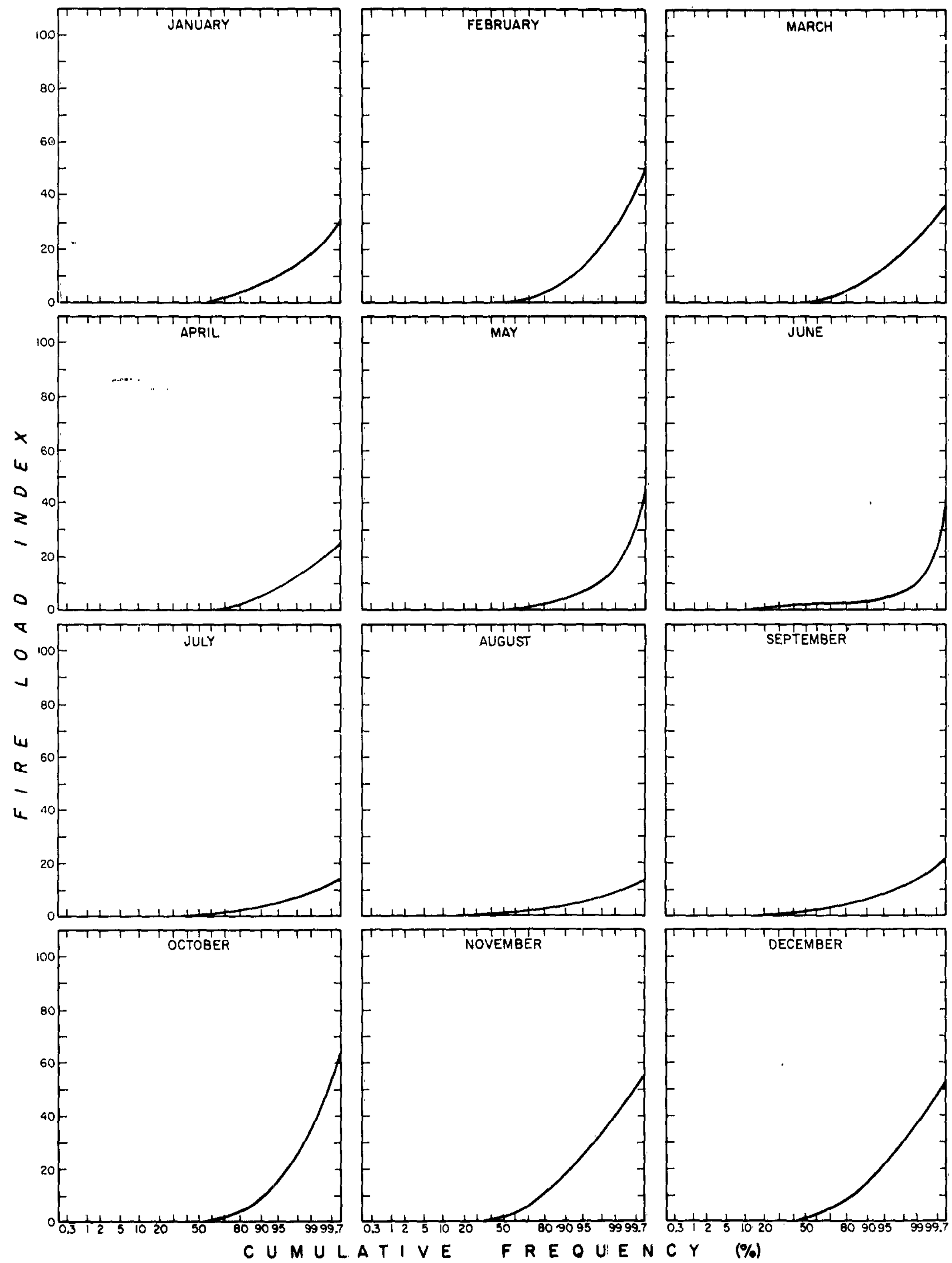
STATION 93193 FRESNO, CALIFORNIA



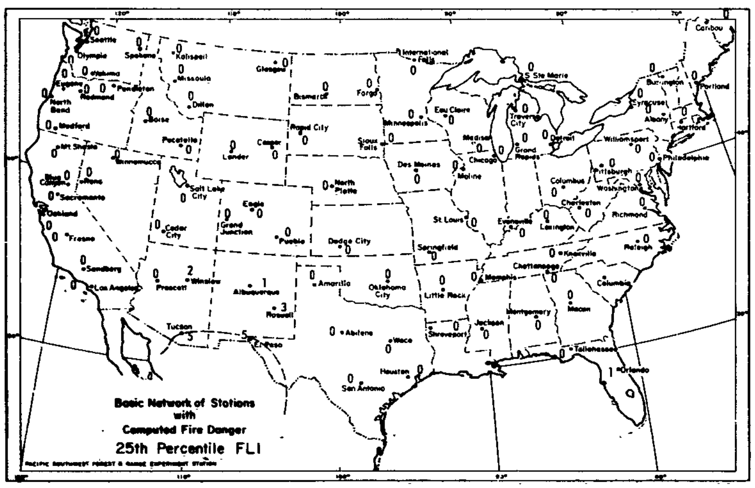
STATION 23187 SANDBERG, CALIFORNIA



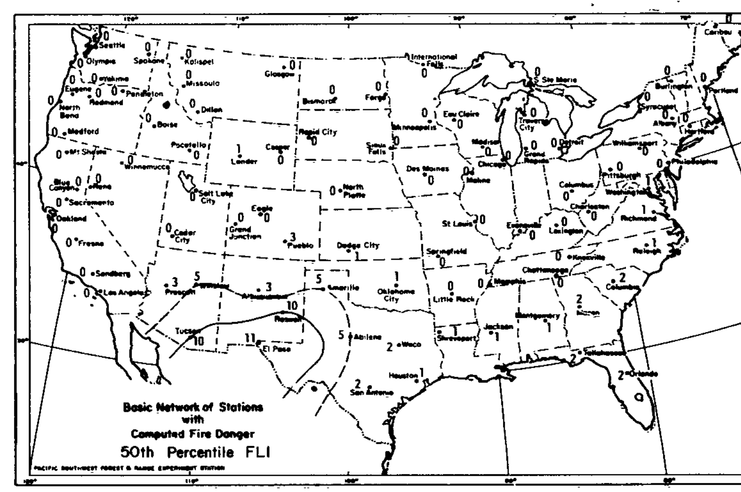
STATION 23174 LOS ANGELES, CALIFORNIA



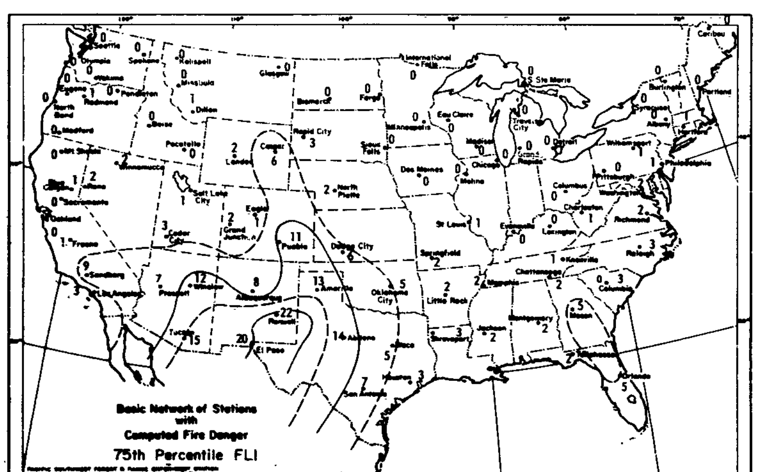
January, 1951-60



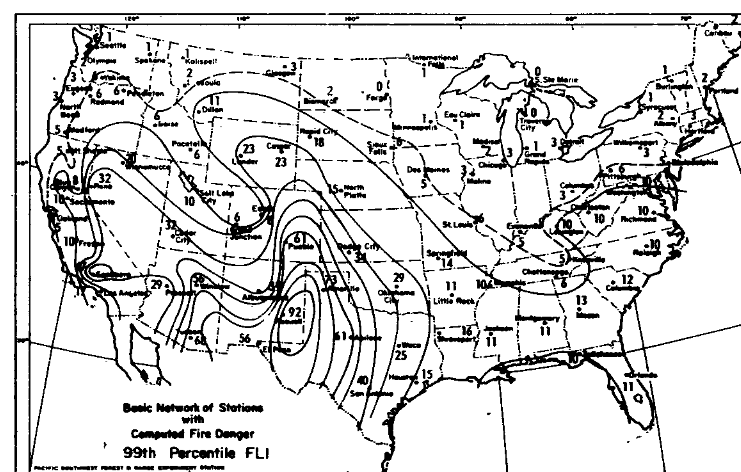
Basic Network of Stations with Computed Fire Danger 25th Percentile FLI



Basic Network of Stations with Computed Fire Danger 50th Percentile FLI

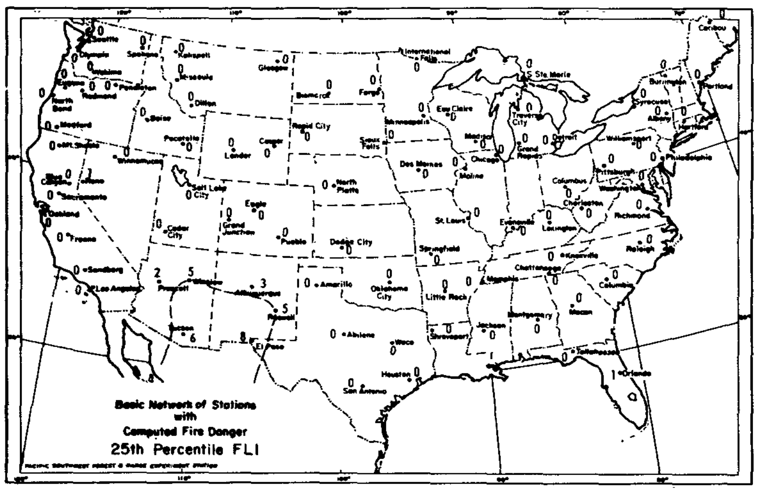


Basic Network of Stations with Computed Fire Danger 75th Percentile FLI



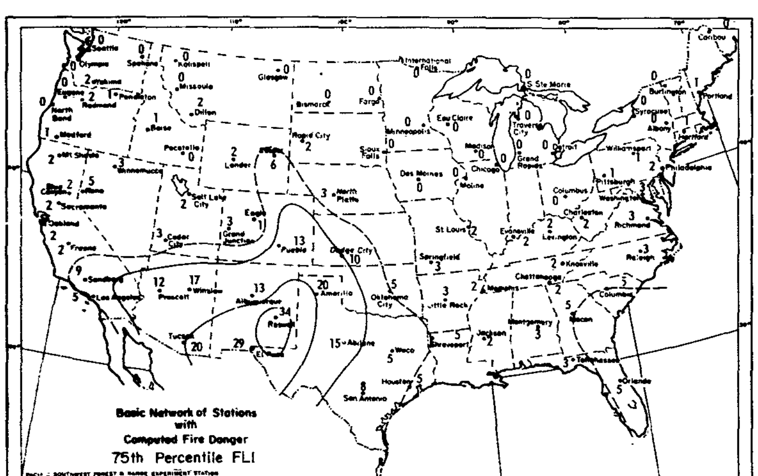
Basic Network of Stations with Computed Fire Danger 99th Percentile FLI

February, 1951-60

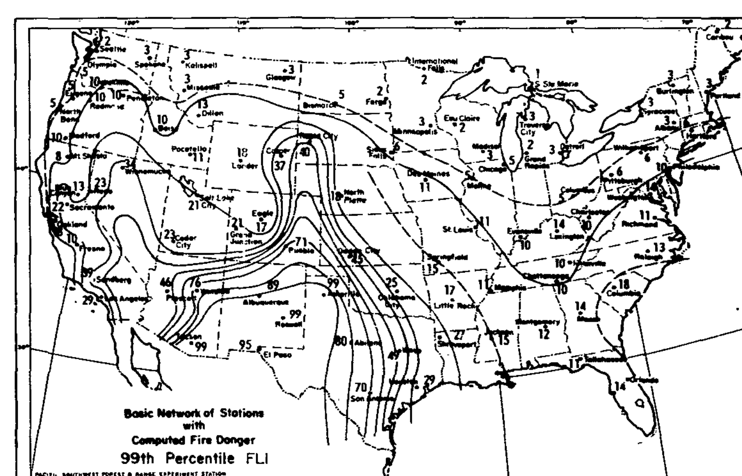


Basic Network of Stations with Computed Fire Danger
25th Percentile FLI

Basic Network of Stations with Computed Fire Danger
50th Percentile FLI

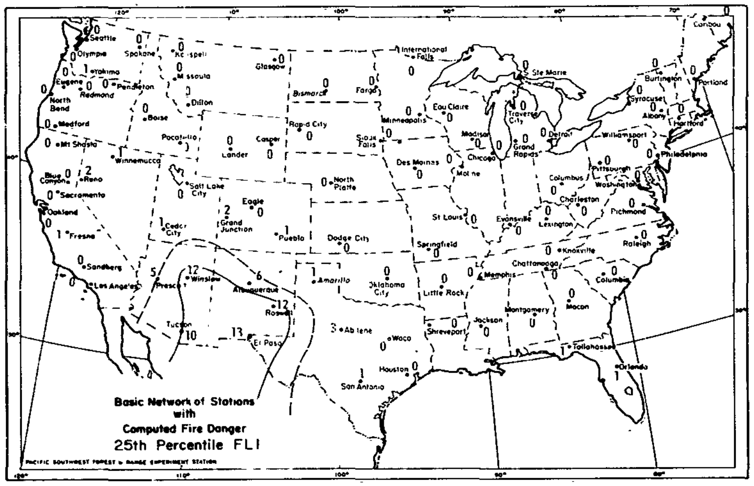


Basic Network of Stations with Computed Fire Danger
75th Percentile FLI

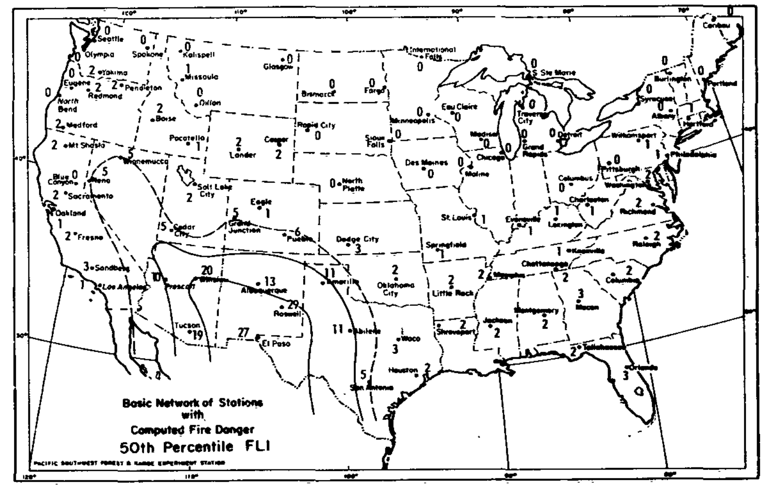


Basic Network of Stations with Computed Fire Danger
99th Percentile FLI

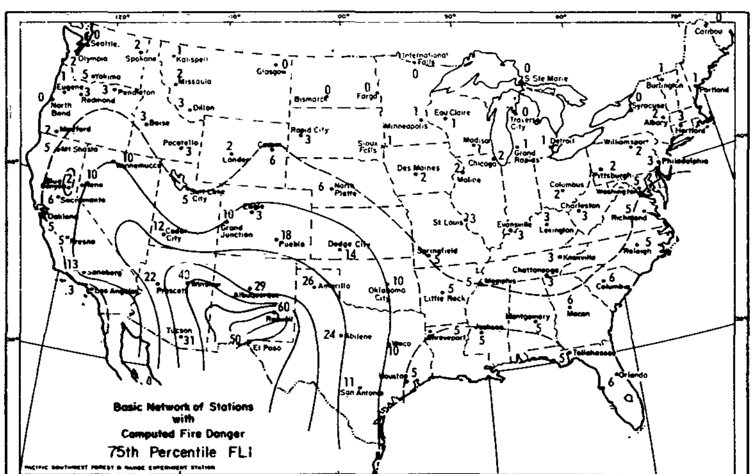
March, 1951-60



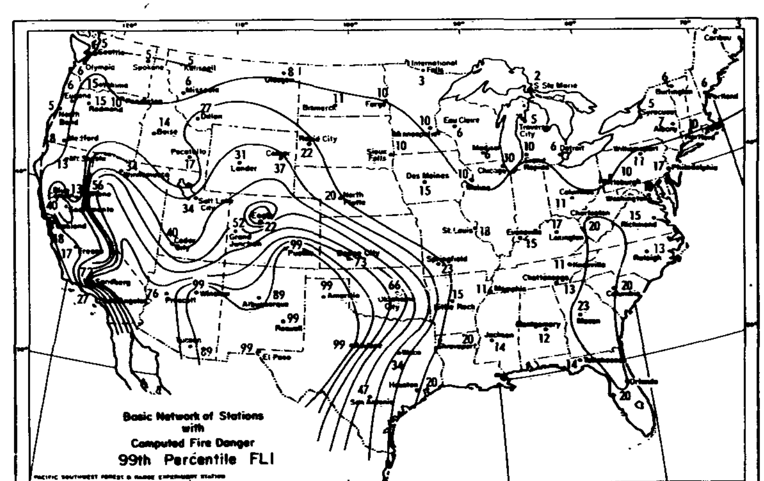
Basic Network of Stations with Computed Fire Danger 25th Percentile FLI



Basic Network of Stations with Computed Fire Danger 50th Percentile FLI

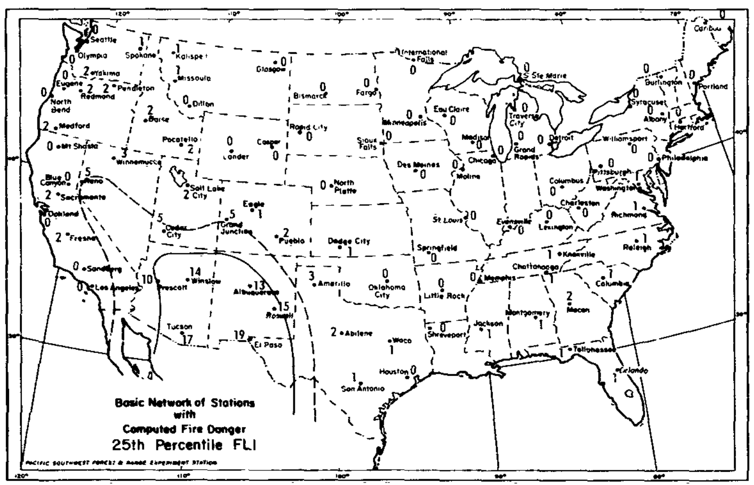


Basic Network of Stations with Computed Fire Danger 75th Percentile FLI

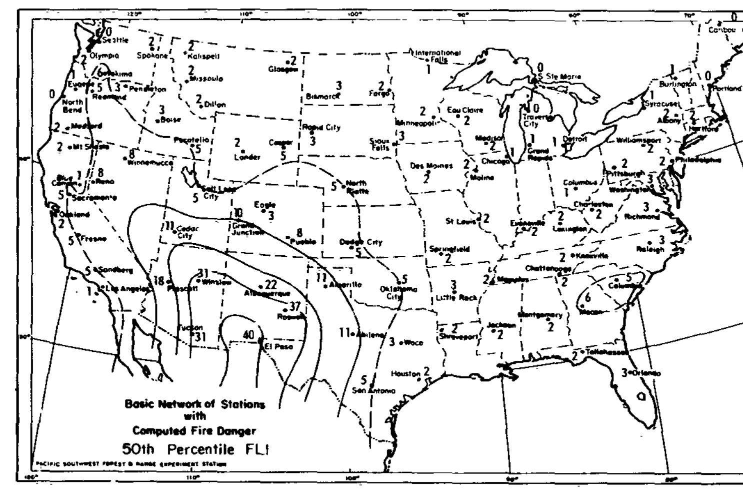


Basic Network of Stations with Computed Fire Danger 99th Percentile FLI

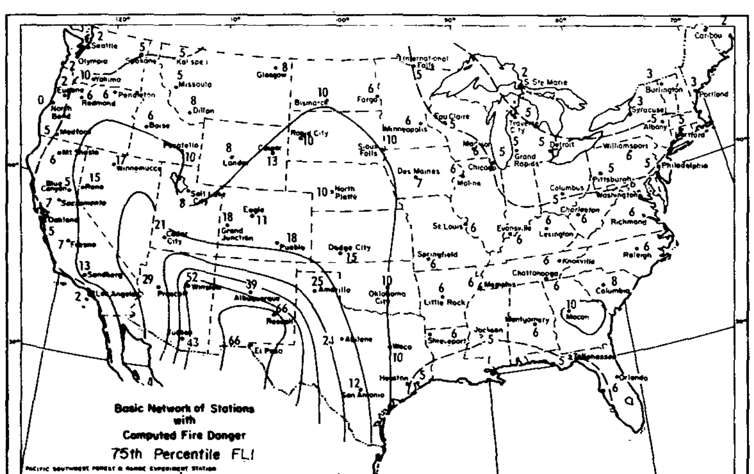
April, 1951-60



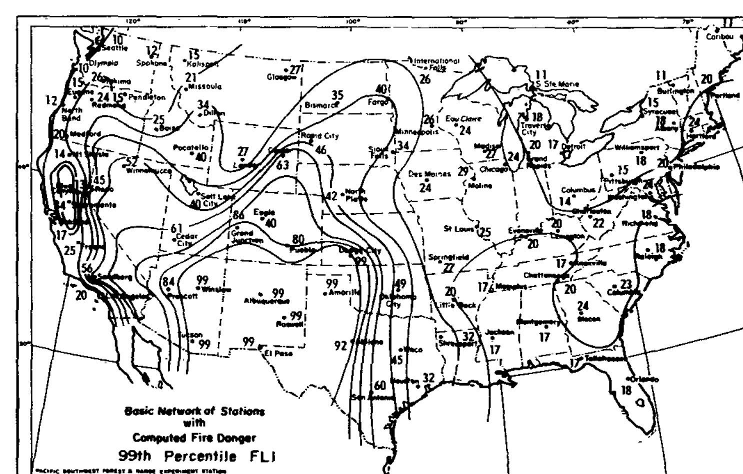
Basic Network of Stations with Computed Fire Danger 25th Percentile FLI



Basic Network of Stations with Computed Fire Danger 50th Percentile FLI

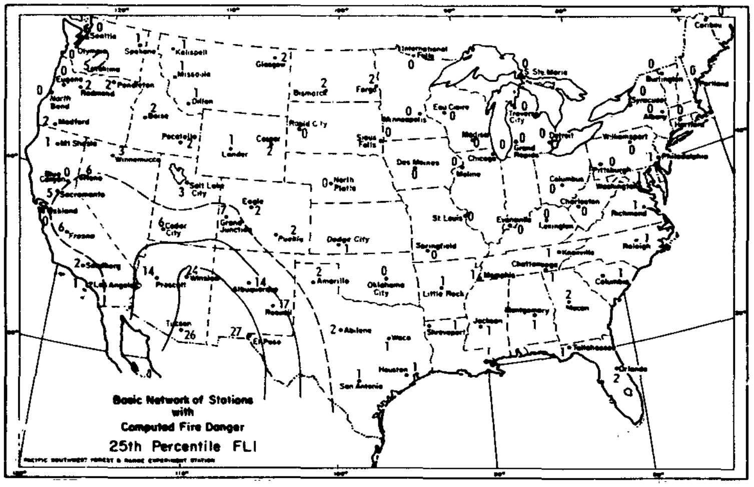


Basic Network of Stations with Computed Fire Danger 75th Percentile FLI

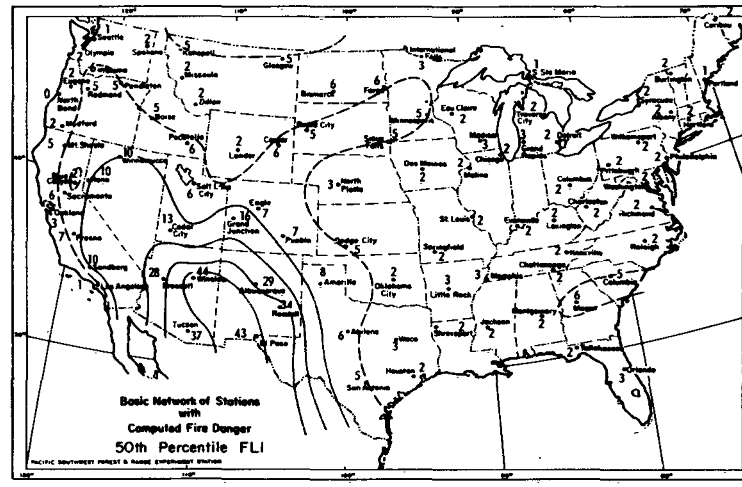


Basic Network of Stations with Computed Fire Danger 99th Percentile FLI

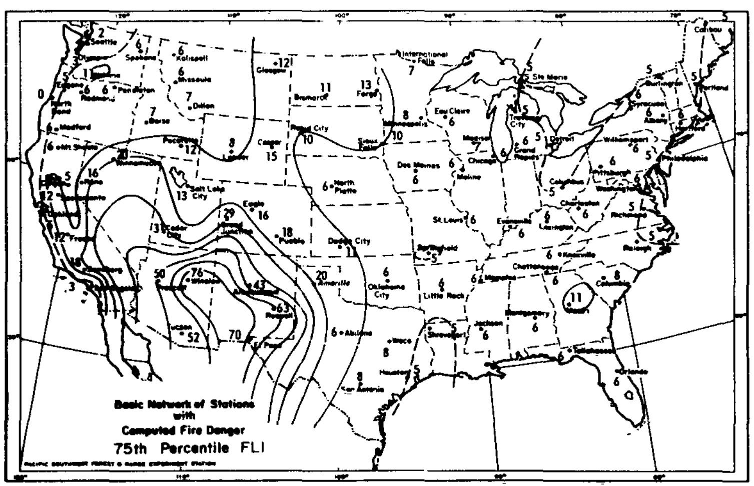
May, 1951-60



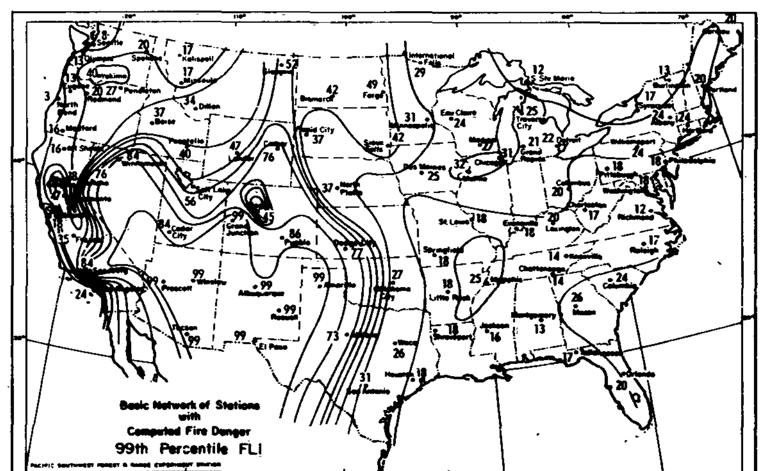
Basic Network of Stations
with
Computed Fire Danger
25th Percentile FLI



Basic Network of Stations
with
Computed Fire Danger
50th Percentile FLI

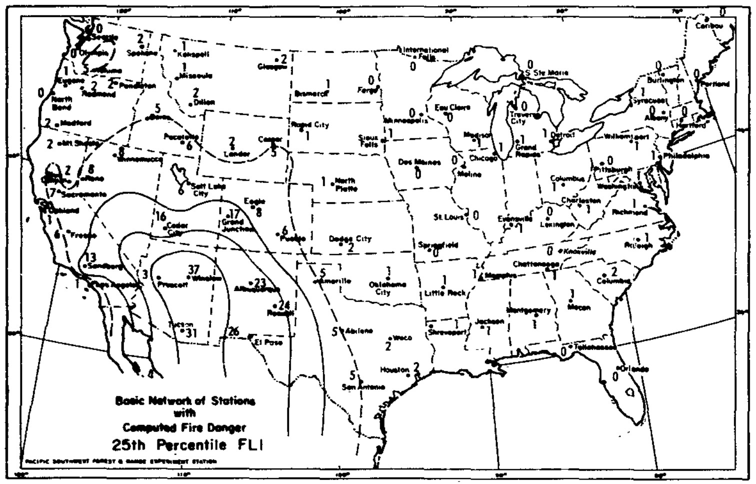


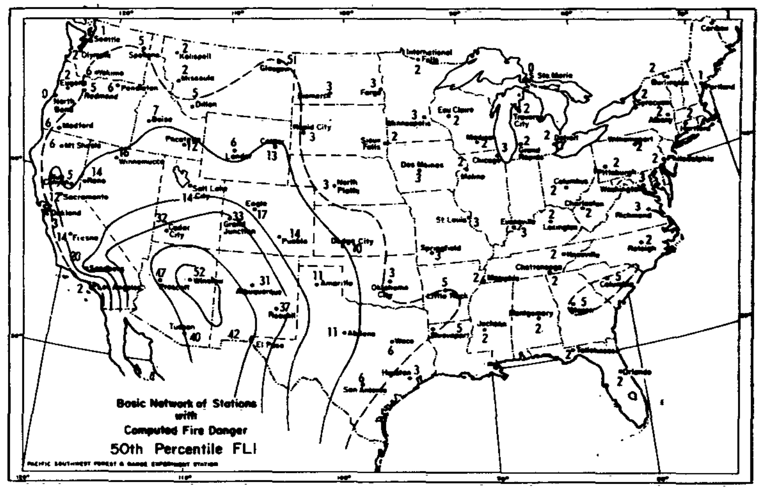
Basic Network of Stations
with
Computed Fire Danger
75th Percentile FLI

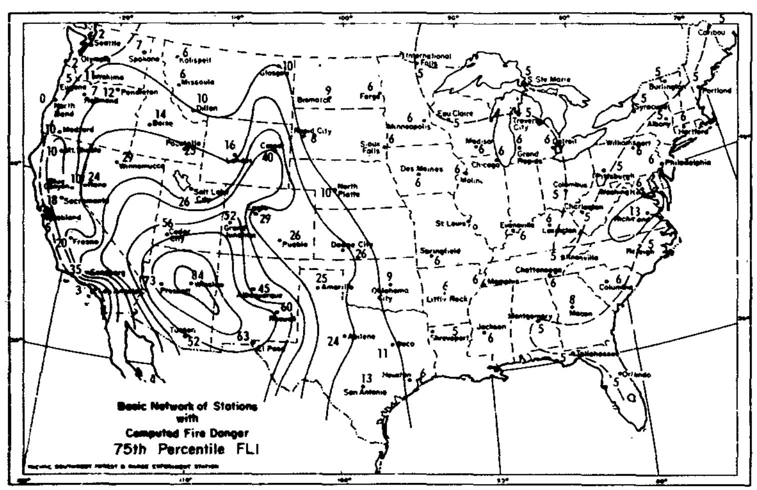


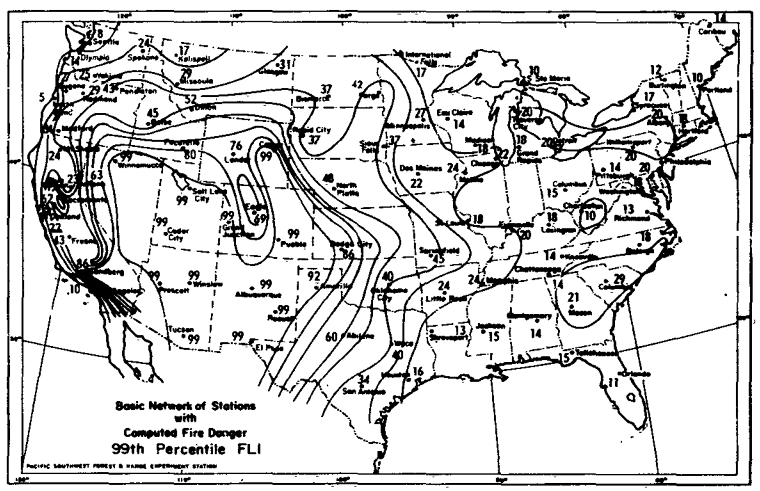
Basic Network of Stations
with
Computed Fire Danger
99th Percentile FLI

June, 1951-60

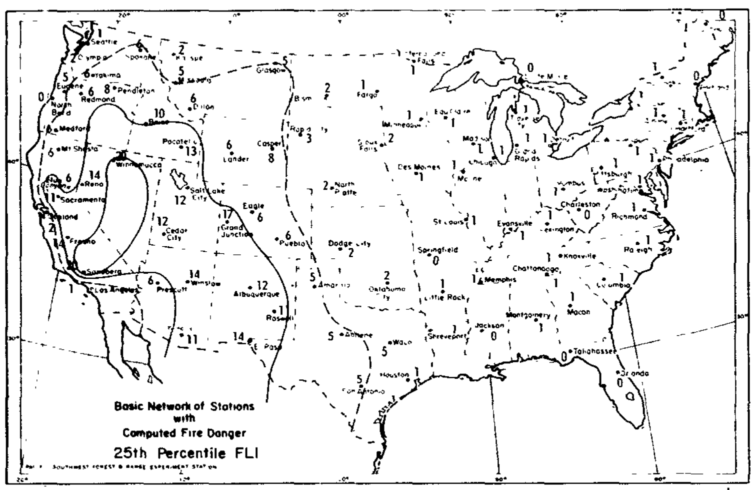

Basic Network of Stations
with
Computed Fire Danger
25th Percentile FLI


Basic Network of Stations
with
Computed Fire Danger
50th Percentile FLI

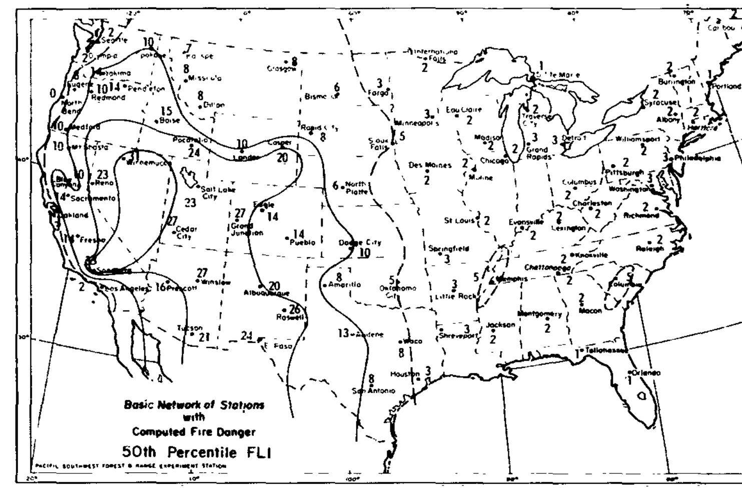

Basic Network of Stations
with
Computed Fire Danger
75th Percentile FLI


Basic Network of Stations
with
Computed Fire Danger
99th Percentile FLI

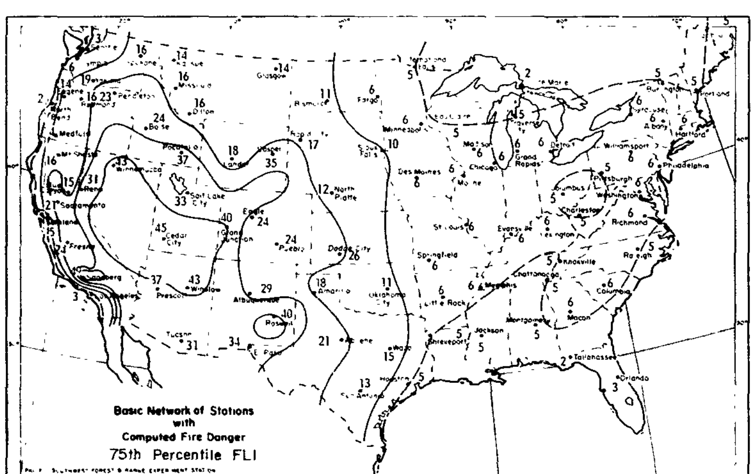
July, 1951-60



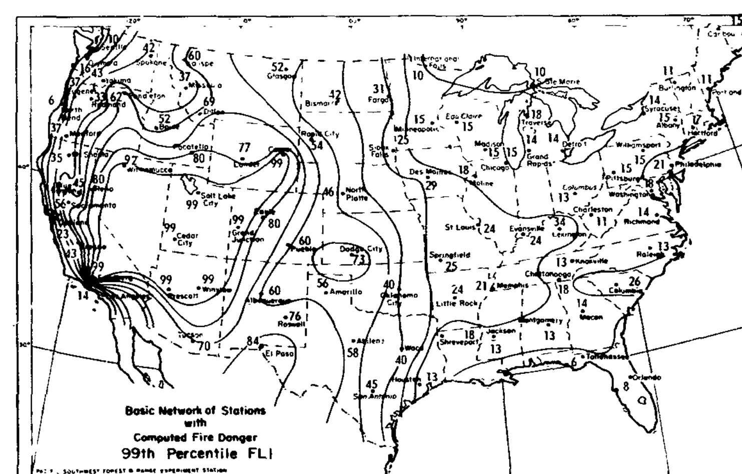
Basic Network of Stations with Computed Fire Danger 25th Percentile FLI



Basic Network of Stations with Computed Fire Danger 50th Percentile FLI

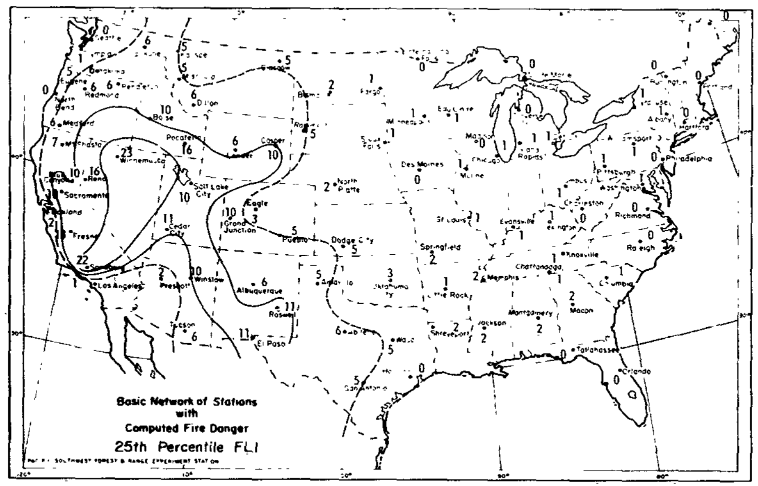


Basic Network of Stations with Computed Fire Danger 75th Percentile FLI

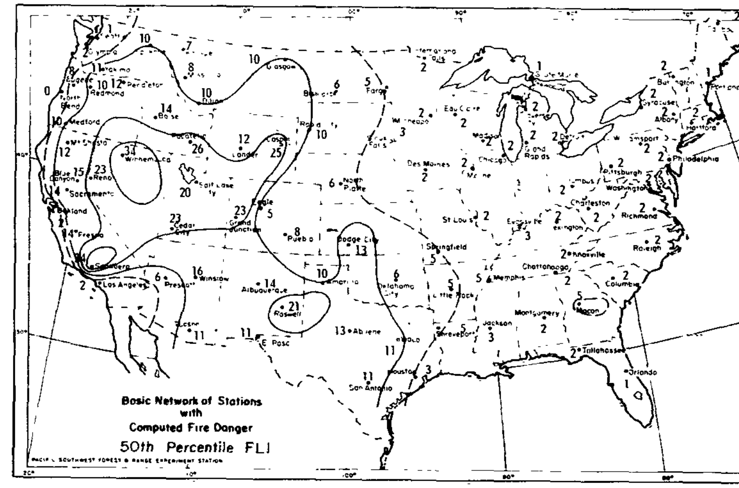


Basic Network of Stations with Computed Fire Danger 99th Percentile FLI

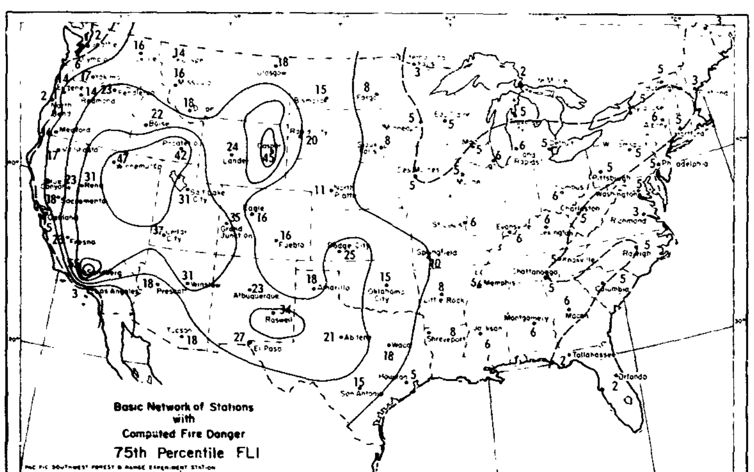
August, 1951-60



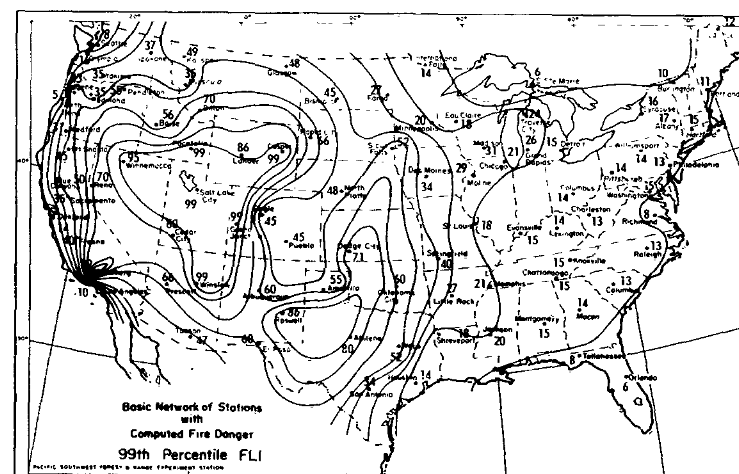
Basic Network of Stations with Computed Fire Danger 25th Percentile FLI



Basic Network of Stations with Computed Fire Danger 50th Percentile FLI

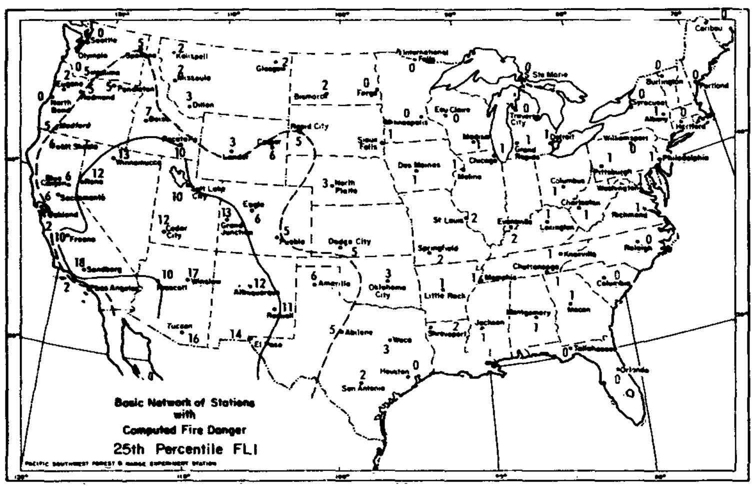


Basic Network of Stations with Computed Fire Danger 75th Percentile FLI



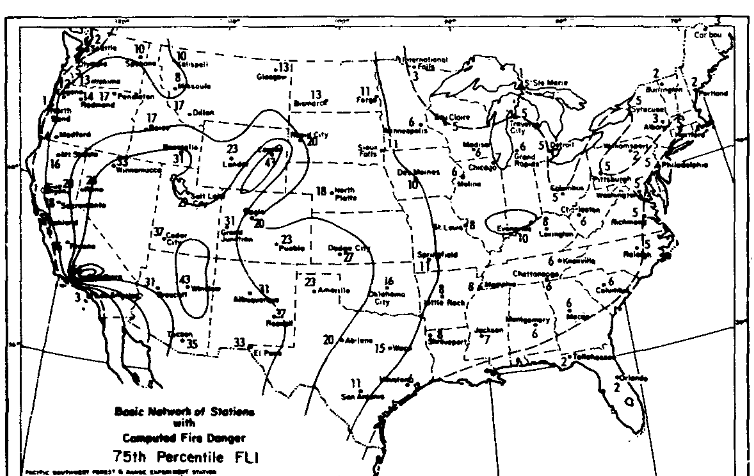
Basic Network of Stations with Computed Fire Danger 99th Percentile FLI

September, 1951-60

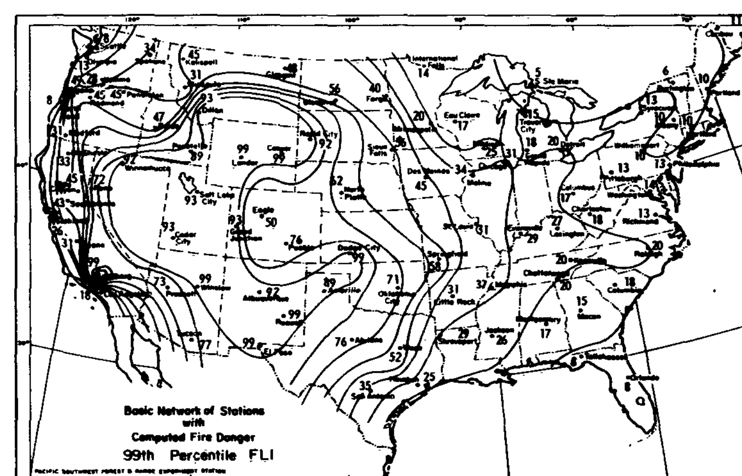


Basic Network of Stations with Computed Fire Danger 25th Percentile FLI

Basic Network of Stations with Computed Fire Danger 50th Percentile FLI



Basic Network of Stations with Computed Fire Danger 75th Percentile FLI



Basic Network of Stations with Computed Fire Danger 99th Percentile FLI

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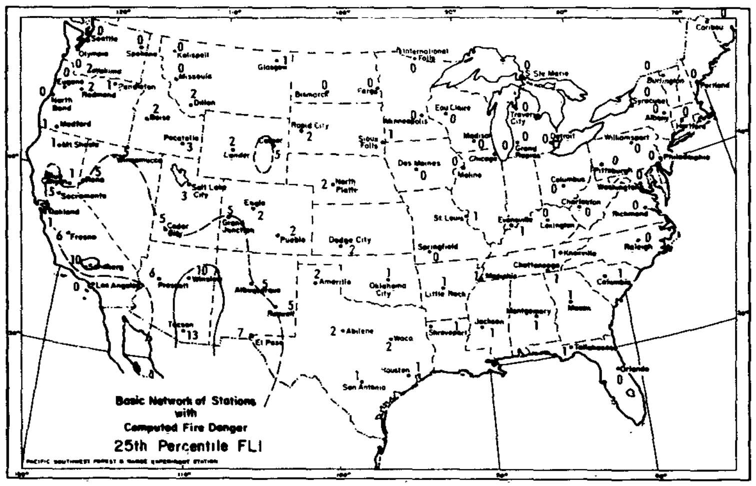

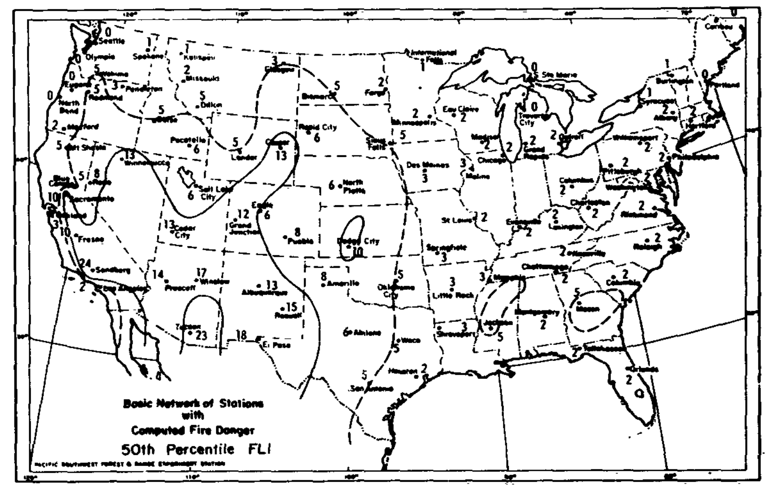

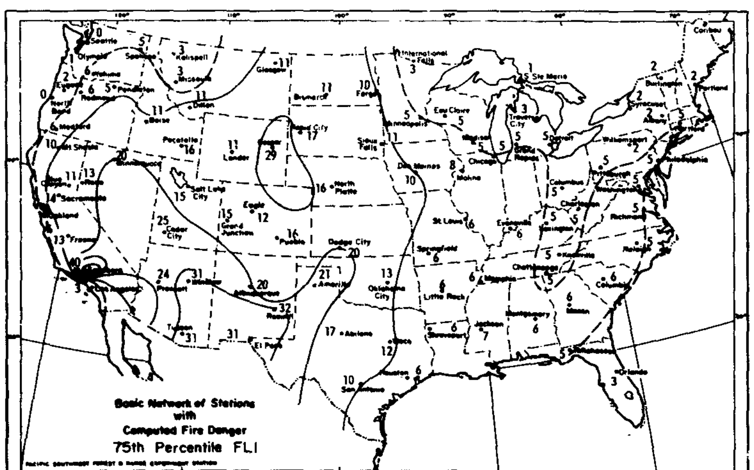

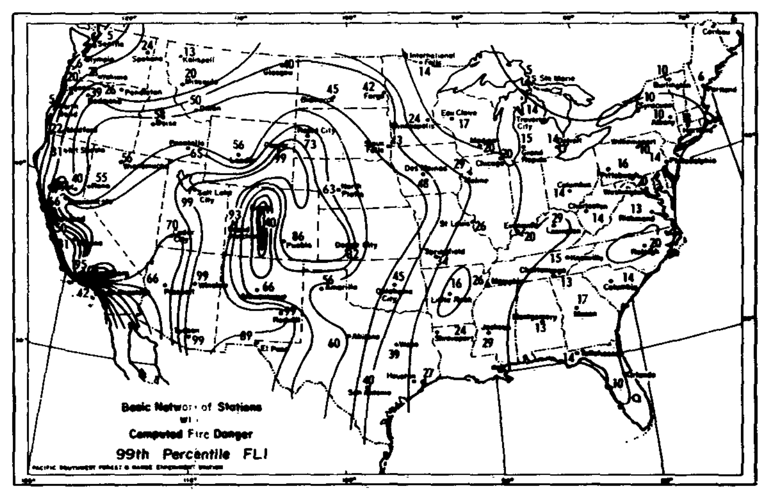

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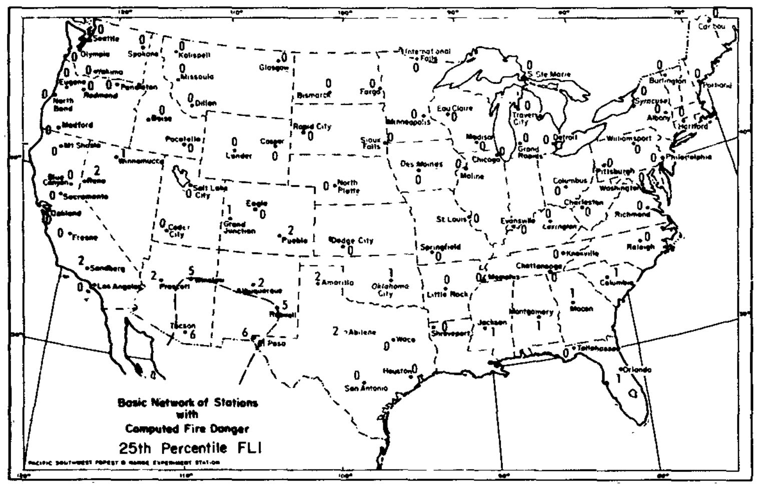
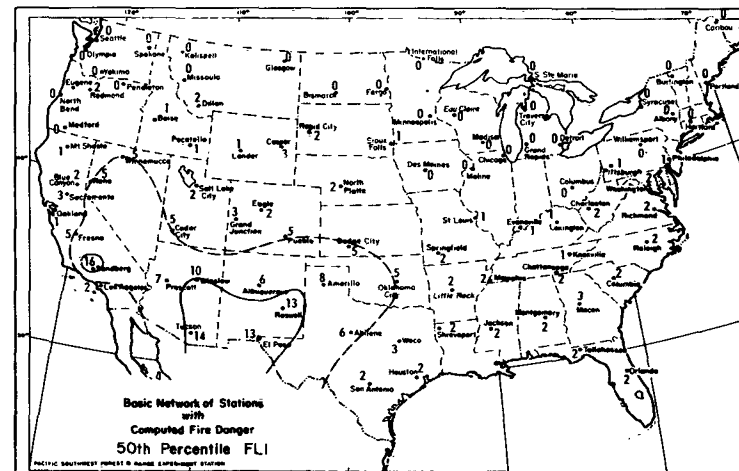
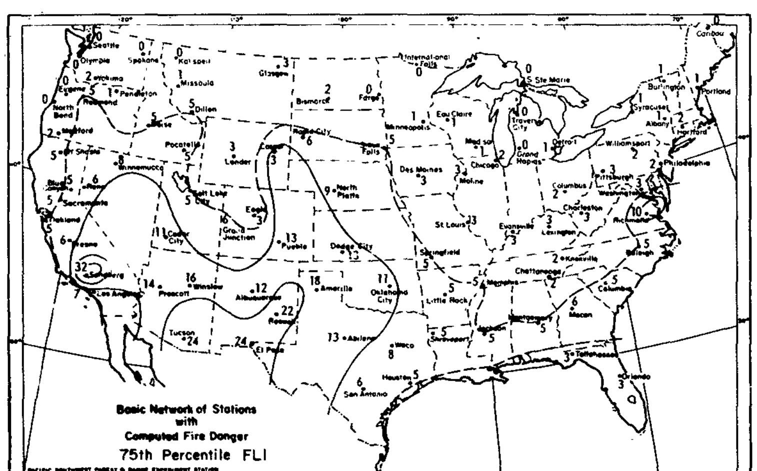
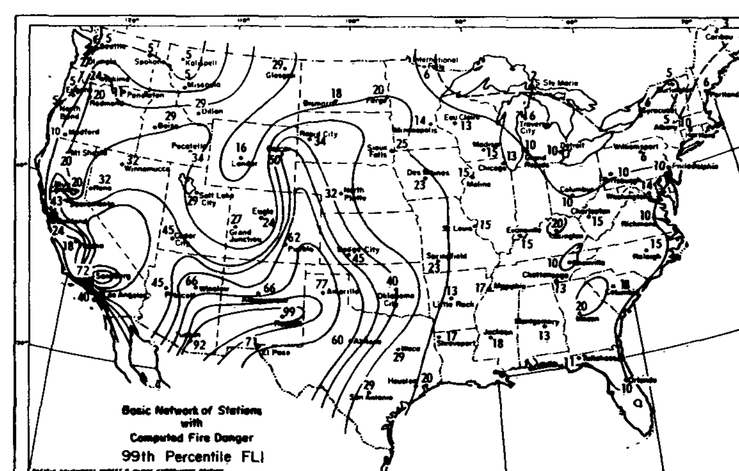
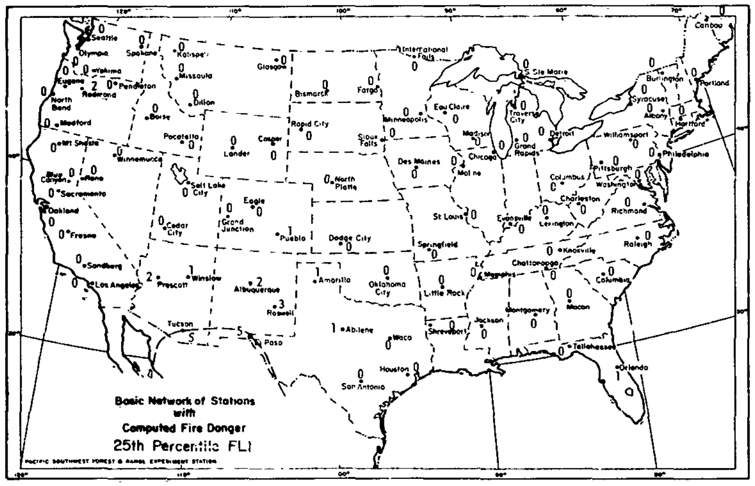

Basic Network of Stations with Computed Fire Danger 25th Percentile FLI


Basic Network of Stations with Computed Fire Danger 50th Percentile FLI

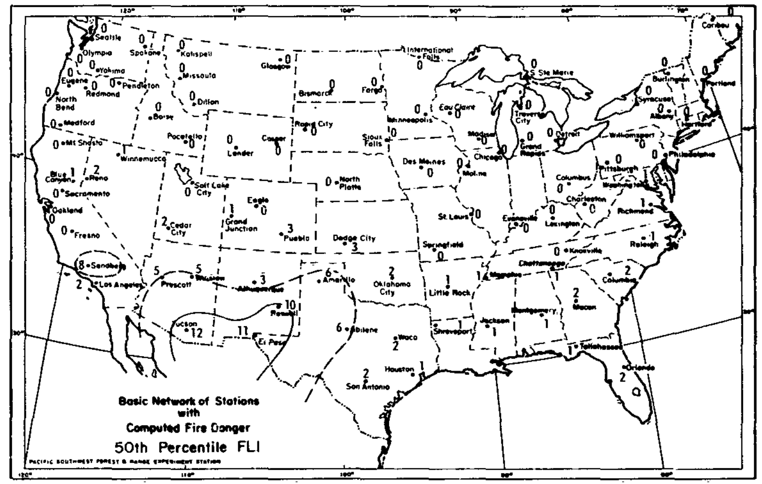

Basic Network of Stations with Computed Fire Danger 75th Percentile FLI


Basic Network of Stations with Computed Fire Danger 99th Percentile FLI

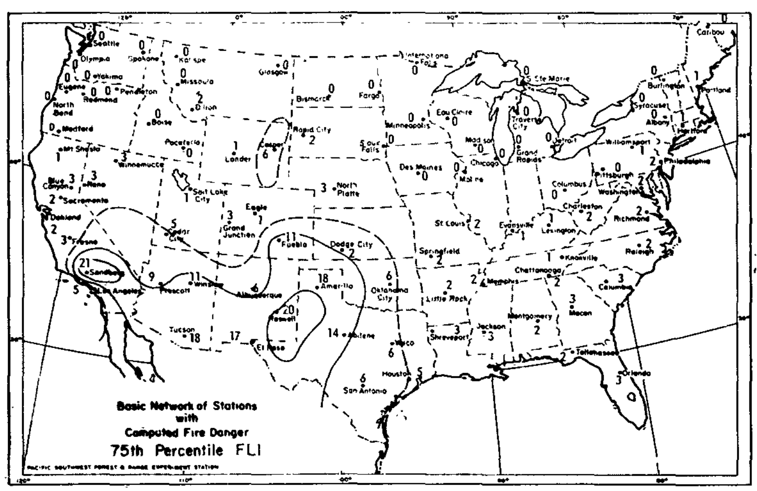
December, 1951-60



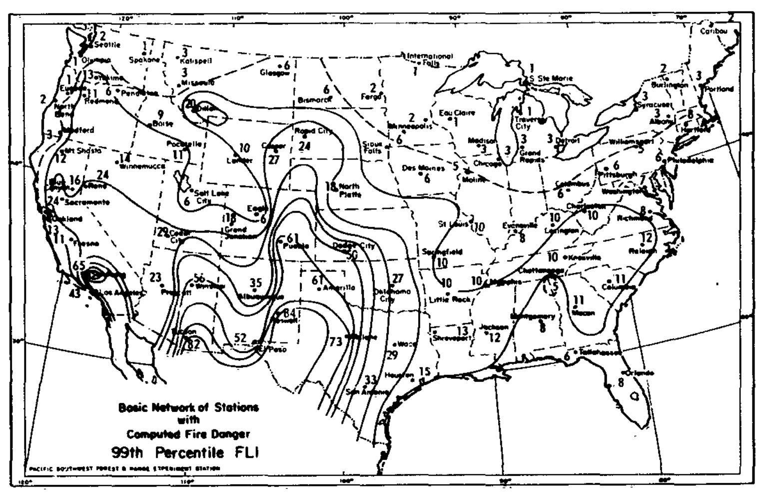
Basic Network of Stations with Computed Fire Danger 25th Percentile FLI



Basic Network of Stations with Computed Fire Danger 50th Percentile FLI



Basic Network of Stations with Computed Fire Danger 75th Percentile FLI



Basic Network of Stations with Computed Fire Danger 99th Percentile FLI

APPENDIX B

MAPS OF SNOW COVER PROBABILITY

The fire danger as determined in this study is based upon measurements of weather elements in the free air and upon the estimated effect of liquid precipitation on the moisture content of heavy fuels. Except for the latter factor, no consideration is given to past weather, or the condition of the fuels due to snow cover. Certainly some of the synoptic weather patterns discussed in this report will occur at times when the fuels are covered with snow and the danger from spreading wildfire is nil, and from spreading urban fire greatly reduced.

Fire weather forecasters will, of course, take into account the ground snow condition in issuing forecasts of impending high fire danger. It should be useful, however, particularly for planning purposes, to have some idea of the probability of snow cover in any particular area during any week of the winter. With this in mind the Forest Service entered into an agreement with the Weather Bureau to support in part a study by the Office of Climatology to determine these probabilities.

The snow cover probability maps were prepared from tabulations of the occurrence of total snow cover and partial snow cover of 1-inch or more depth at the end of each of 17 weeks for each 1-degree square over the United States. Total snow cover was defined to be a square more than one-half covered with snow, and partial cover was defined to be a square one-half or less covered with snow. The latter class appeared to be desirable since there were squares in mountainous areas which had a high frequency of squares with less than half coverage.

The source of data was the "Depth of Snow on the Ground" maps of the U.S. Weather Bureau Weekly Weather and Crop Bulletin. These maps show the areas at the end of each week covered with 1 inch or more of snow. The maps are published for the period beginning with the first week in December to the last week in March. Since the dates of weeks vary from year to year, the first week was defined as ending on December 1 through December 7, and the last week as ending on March 23 through March 29. The maps are labeled with the middle day of the week. Maps were based on a consistent criterion, i.e., 1 inch or more snow cover. This criterion went into effect in January 1949. Hence, the maps were based generally on the records of the 15 winters 1948-49 through 1962-63. Due to differences in starting dates, the first week in December has a 5-year record. Because of the change to the 1-inch criterion in 1949, and because one week of record is missing, week two in December has 13 years of record and weeks three and four have 14 years of record. All of the weeks in January, February, and March have 15 years of record.

Probabilities of partial or total coverage were estimated by dividing the counts for each square by the total number of years of record. The probability estimates for total coverage are shown at the top of the square and those for partial and/or total coverage at the bottom of the square. The probability estimates for partial coverage alone may be obtained by subtracting

the upper figures from the lower. When the two probabilities are equal, it is clear that there were no occurrences of partial coverage in the sample. Since snow cover is a continuously varying quantity, the probabilities may be applied to any day during the week for which they were estimated, or they may be viewed as an annual march of probability by applying the map values to the middle day of each week.

Since it is usually desirable to give an indication of the precision of probability estimates, the following table gives 0.80 confidence intervals for each probability "p" and length of record "n" occurring on the maps.

0.80 Confidence Intervals for p

n = 15

p	.07	.13	.20	.27	.33	.40	.47	.53	.60	.67	.73	.80	.87	.93
U	.23	.32	.39	.47	.53	.59	.66	.72	.78	.83	.88	.93	.97	.98
L	.02	.03	.07	.12	.17	.22	.28	.34	.41	.47	.53	.61	.68	.77

n = 14

p	.07	.14	.21	.29	.36	.43	.50	.57	.64	.71	.79	.86	.93
U	.23	.34	.41	.50	.57	.63	.70	.76	.82	.87	.93	.97	.98
L	.02	.03	.07	.13	.18	.24	.30	.37	.43	.50	.54	.66	.77

n = 13

p	.08	.15	.23	.31	.38	.46	.54	.62	.69	.77	.85	.92
U	.27	.35	.44	.53	.60	.67	.73	.80	.86	.92	.96	.98
L	.02	.04	.08	.14	.20	.27	.33	.40	.47	.56	.65	.73

n = 5

p	.20	.40	.60	.80
U	.42	.62	.78	.93
L	.07	.22	.38	.58

The confidence intervals have the usual interpretation; that is, the probability of the true or population value of "p" lying on the interval (L, U) is 0.80.

Because maps from which the probabilities were calculated were available only for the December through March period, the snow cover probability maps are also limited to that period. Similar probabilities for weeks in the early fall and late spring would also be useful, but the job of calculating them would be costly because it would be necessary to go to the individual station observations.

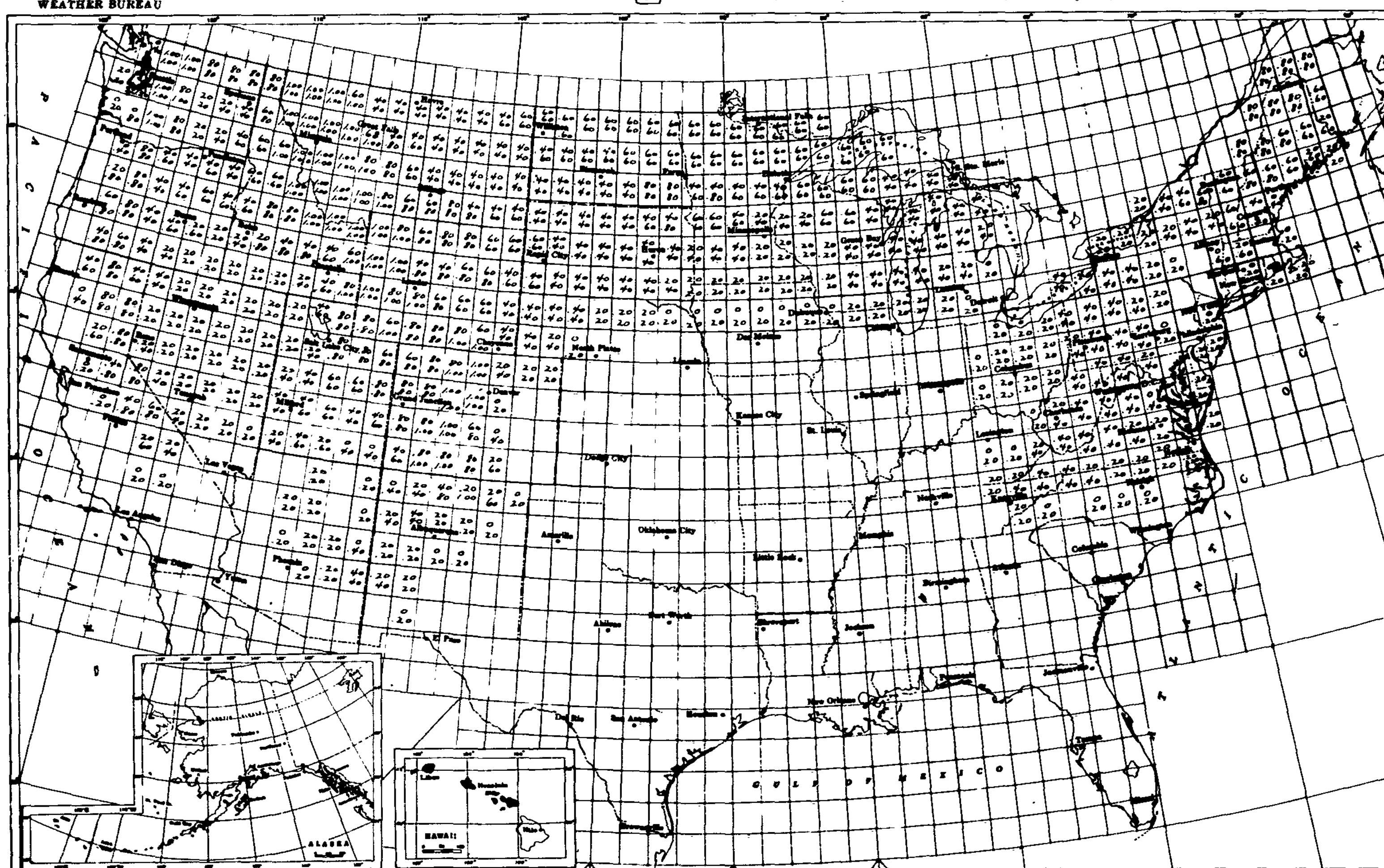
UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

December 4

DEPTH OF SNOW 1 INCH OR MORE

T / P

T - PROBABILITY OF SQUARE OVER 1/2 COVERED.
P - PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



Base map by United States Weather Bureau

SCALE 1:10,000,000
ALBERS EQUAL AREA PROJECTION — STANDARD PARALLELS 29½° AND 45½°

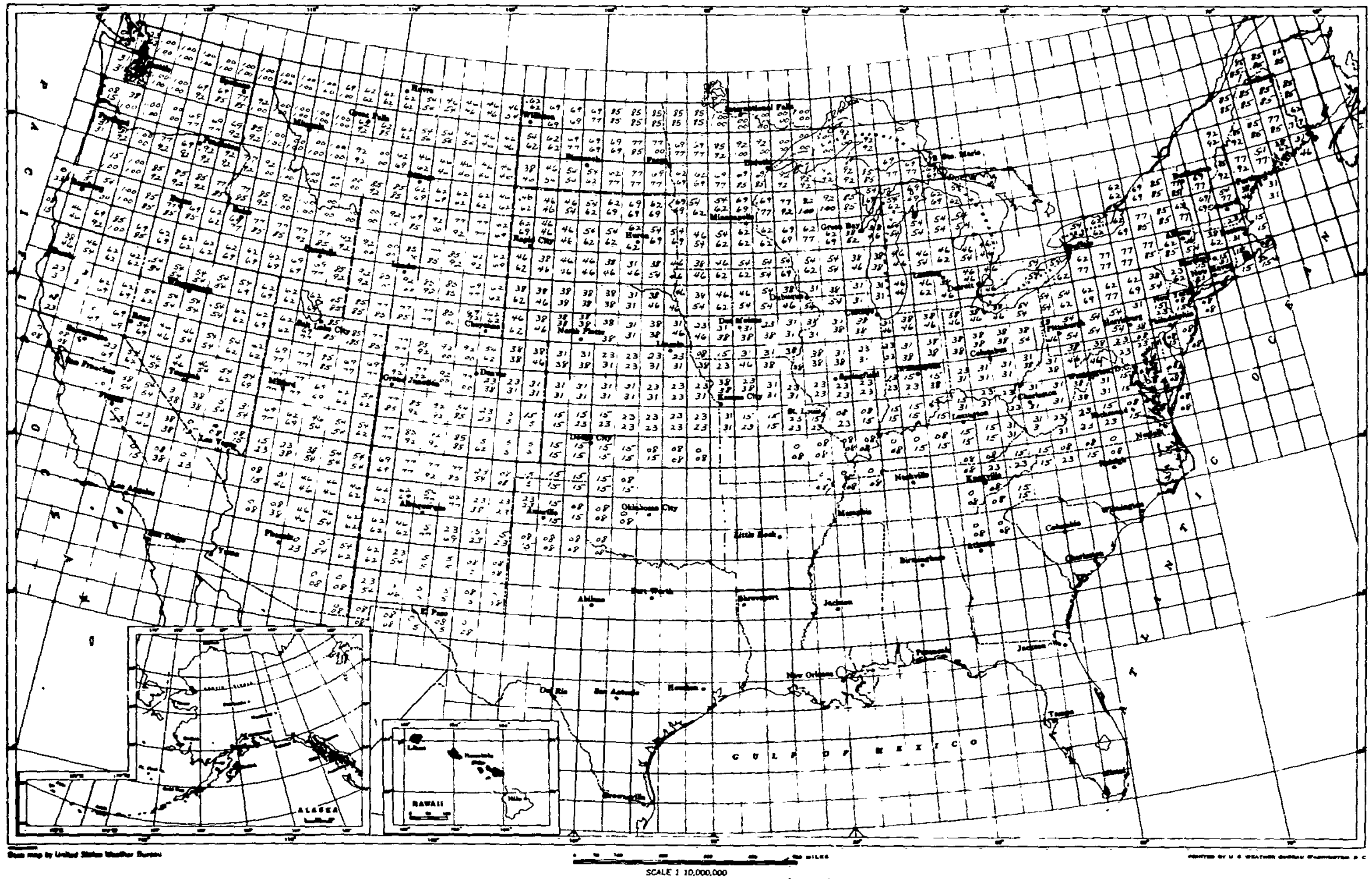
UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

December 11   2

T
P

T = PROBABILITY OF SQUARE OVER 1/2 COVERED.
P = PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



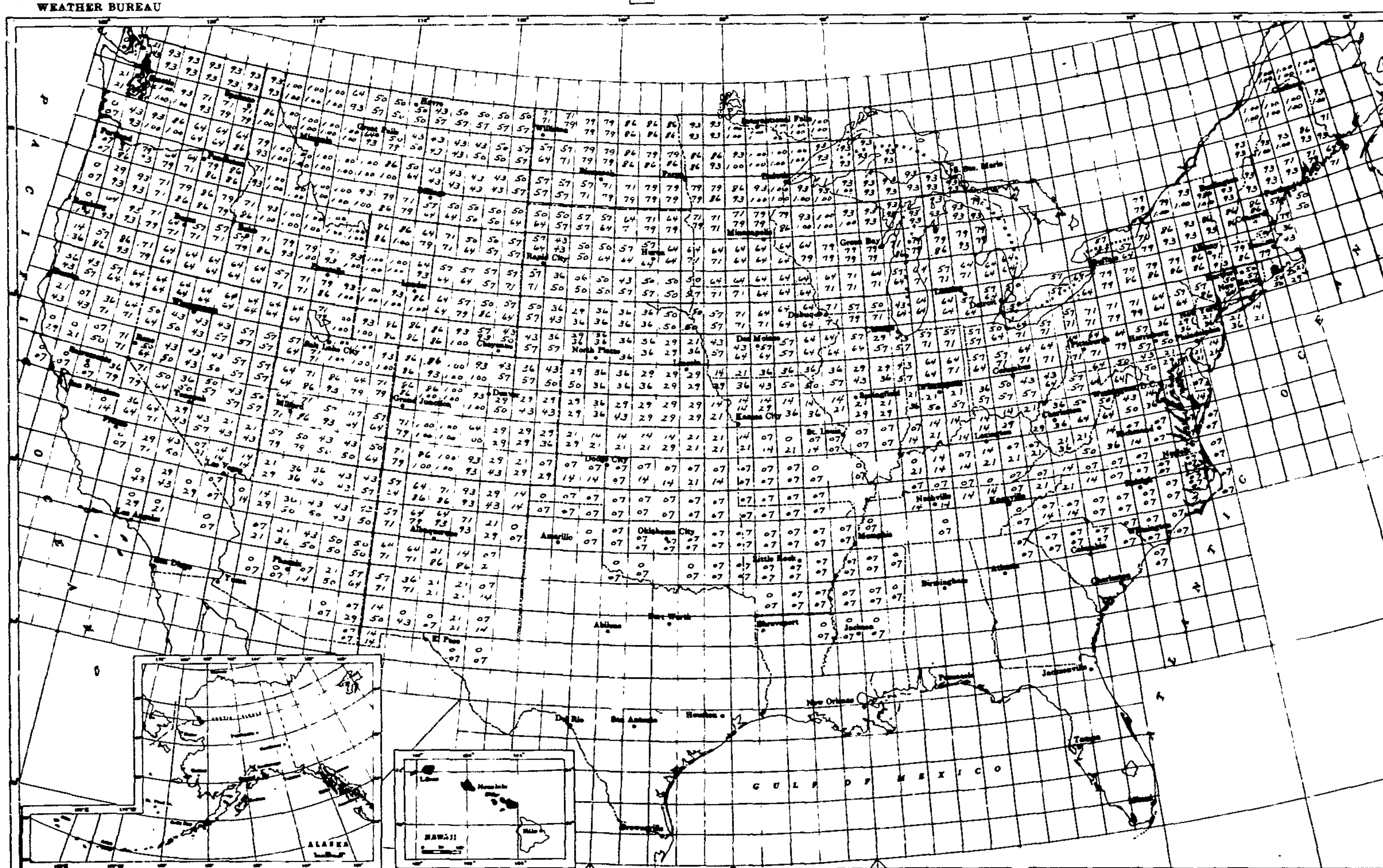
UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

December 18

T
P

T = PROBABILITY OF SQUARE OVER 1/2 COVERED.
P = PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



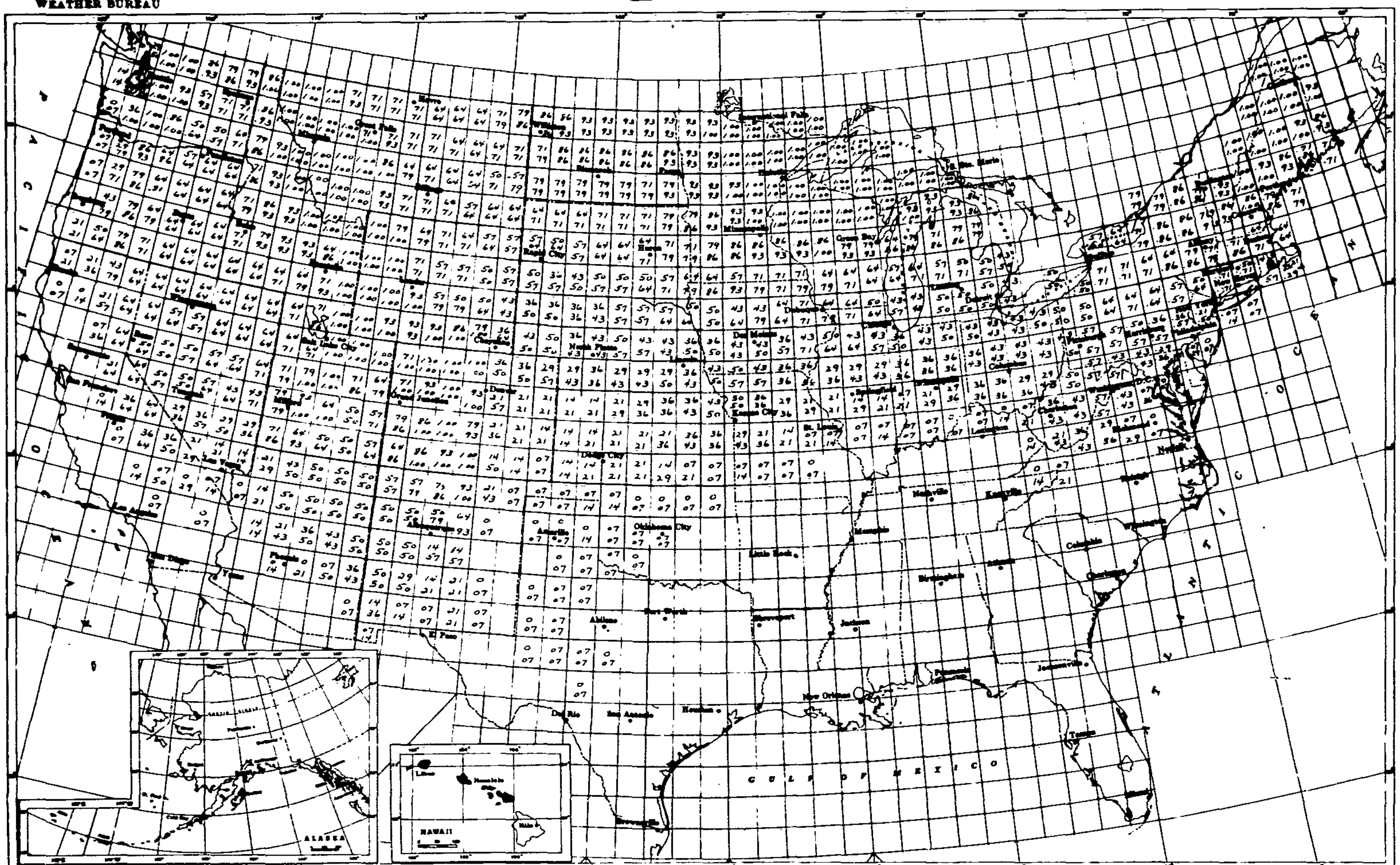
UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

December 25

T
P

T - PROBABILITY OF SQUARE OVER 1/2 COVERED.
P - PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



Base map by United States Weather Bureau

SCALE 1:10,000,000
ALBERS EQUAL AREA PROJECTION - STANDARD PARALLELS 29½° AND 45½°

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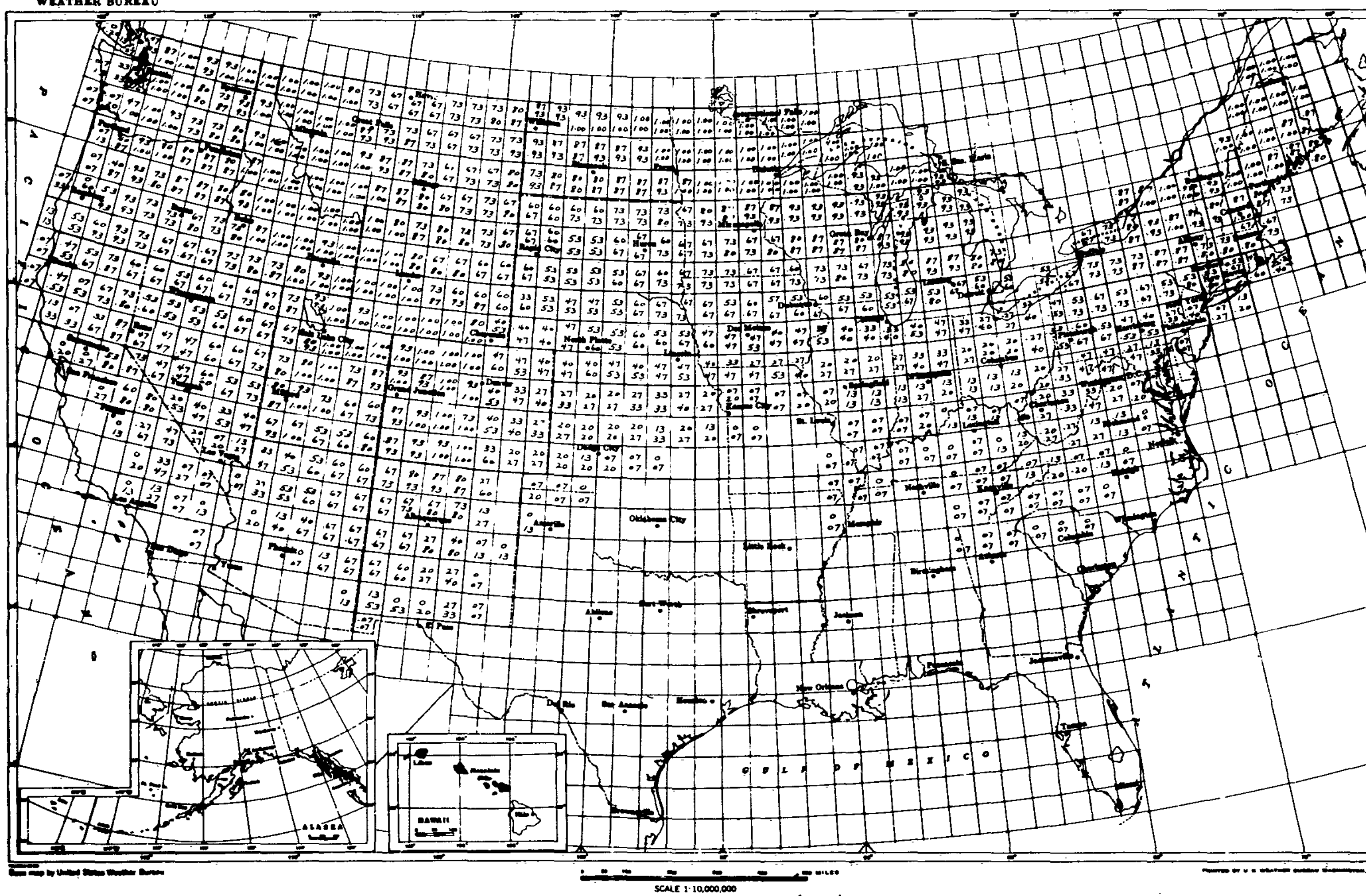
UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

January 1

T = PROBABILITY OF SQUARE OVER 1/2 COVERED.
P = PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

January 8

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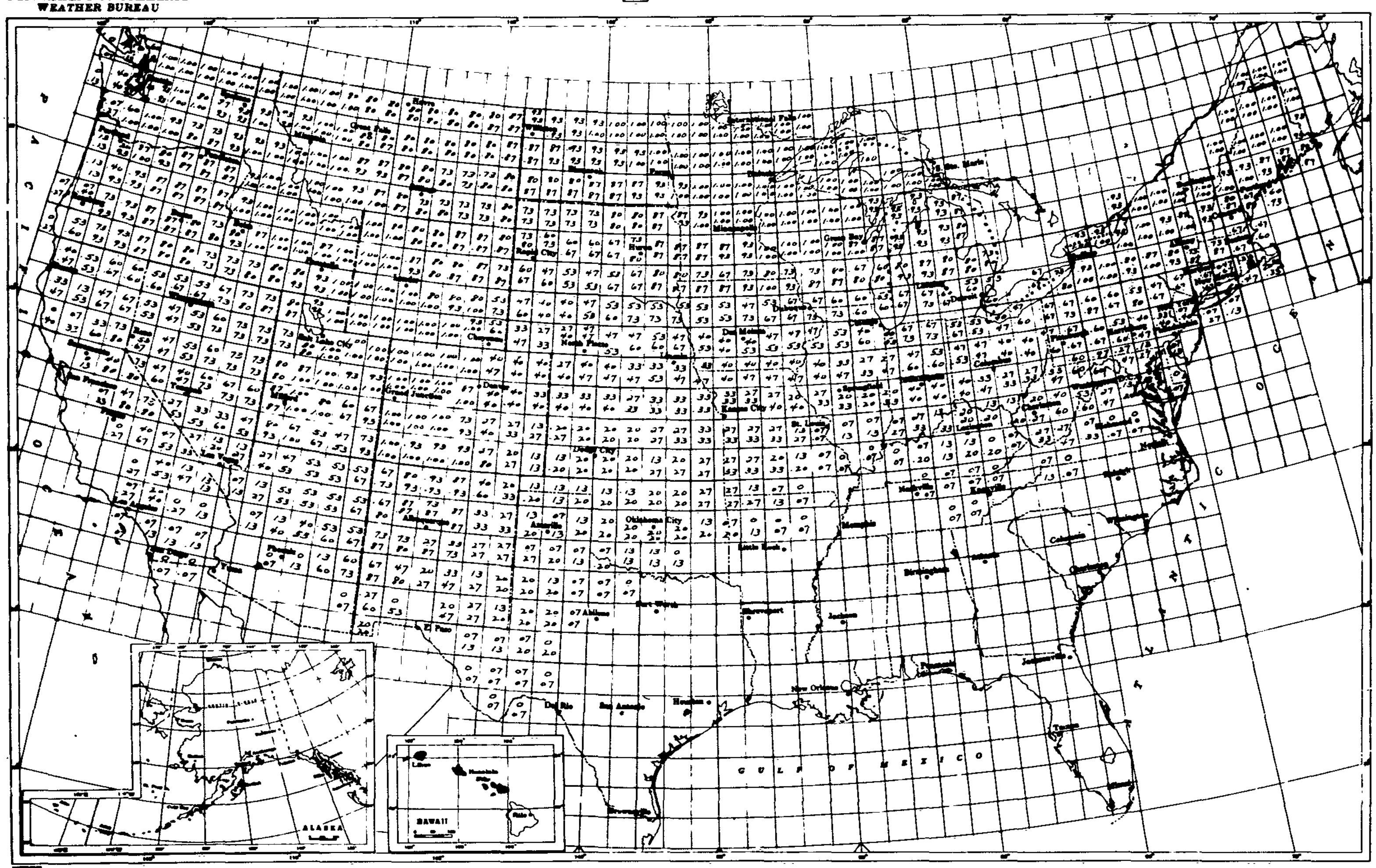
P = PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



Base map by United States Weather Bureau

SCALE 1:10,000,000
ALBERS EQUAL AREA PROJECTION — STANDARD PARALLELS 29½° AND 45½°

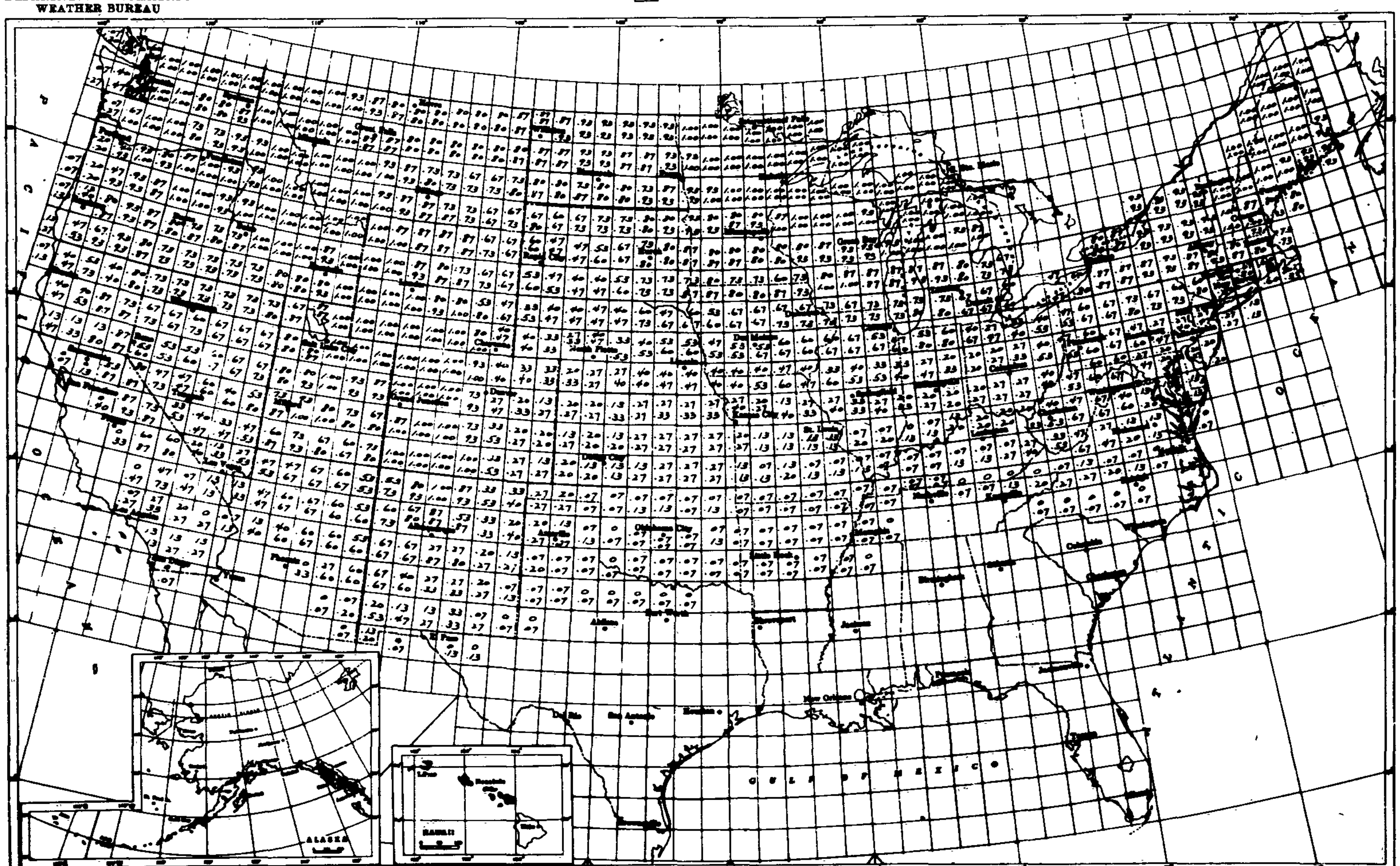
UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

January 15

T
P

T = PROBABILITY OF SQUARE OVER 1/2 COVERED.
P = PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



Base map by United States Weather Bureau

SCALE 1:10,000,000

ALBERS EQUAL AREA PROJECTION — STANDARD PARALLELS 29½° AND 45½°

UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

January 22

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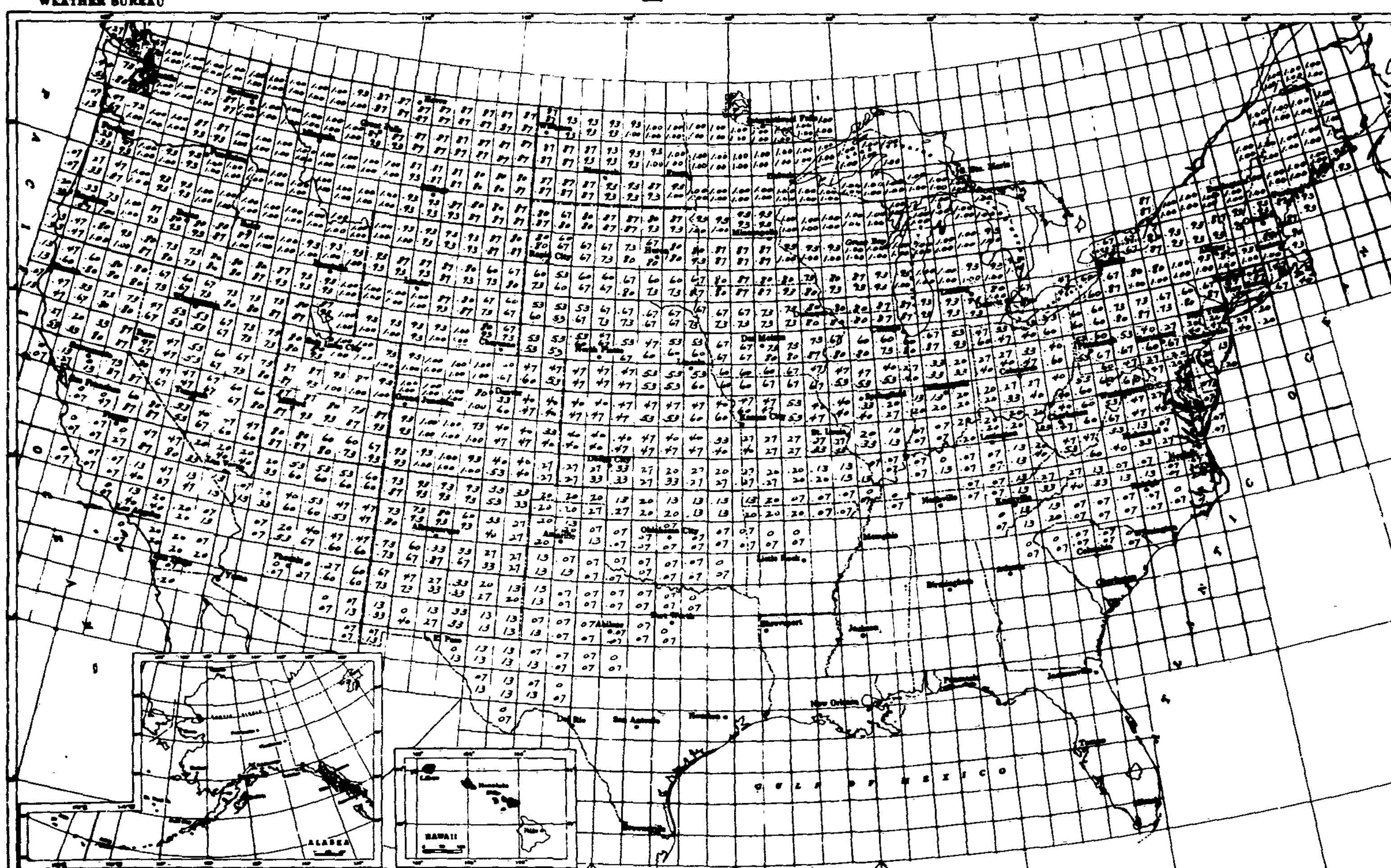
P = PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



Base map by United States Weather Bureau

SCALE 1:10,000,000

ALBERS EQUAL AREA PROJECTION — STANDARD PARALLELS 29½° AND 45½°

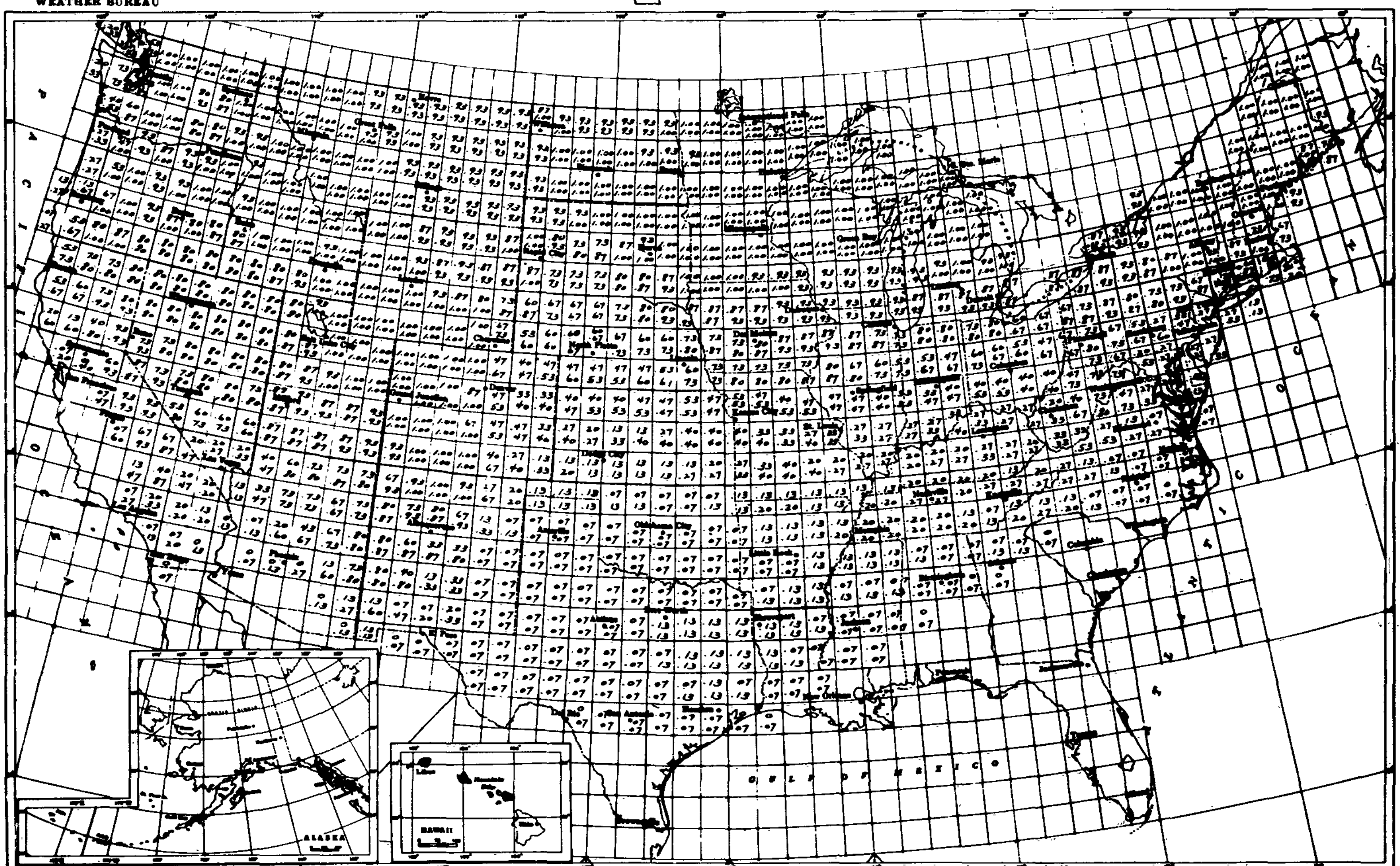
UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

January 29

T
P

T = PROBABILITY OF SQUARE OVER 1/2 COVERED.
P = PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



Base map by United States Weather Bureau

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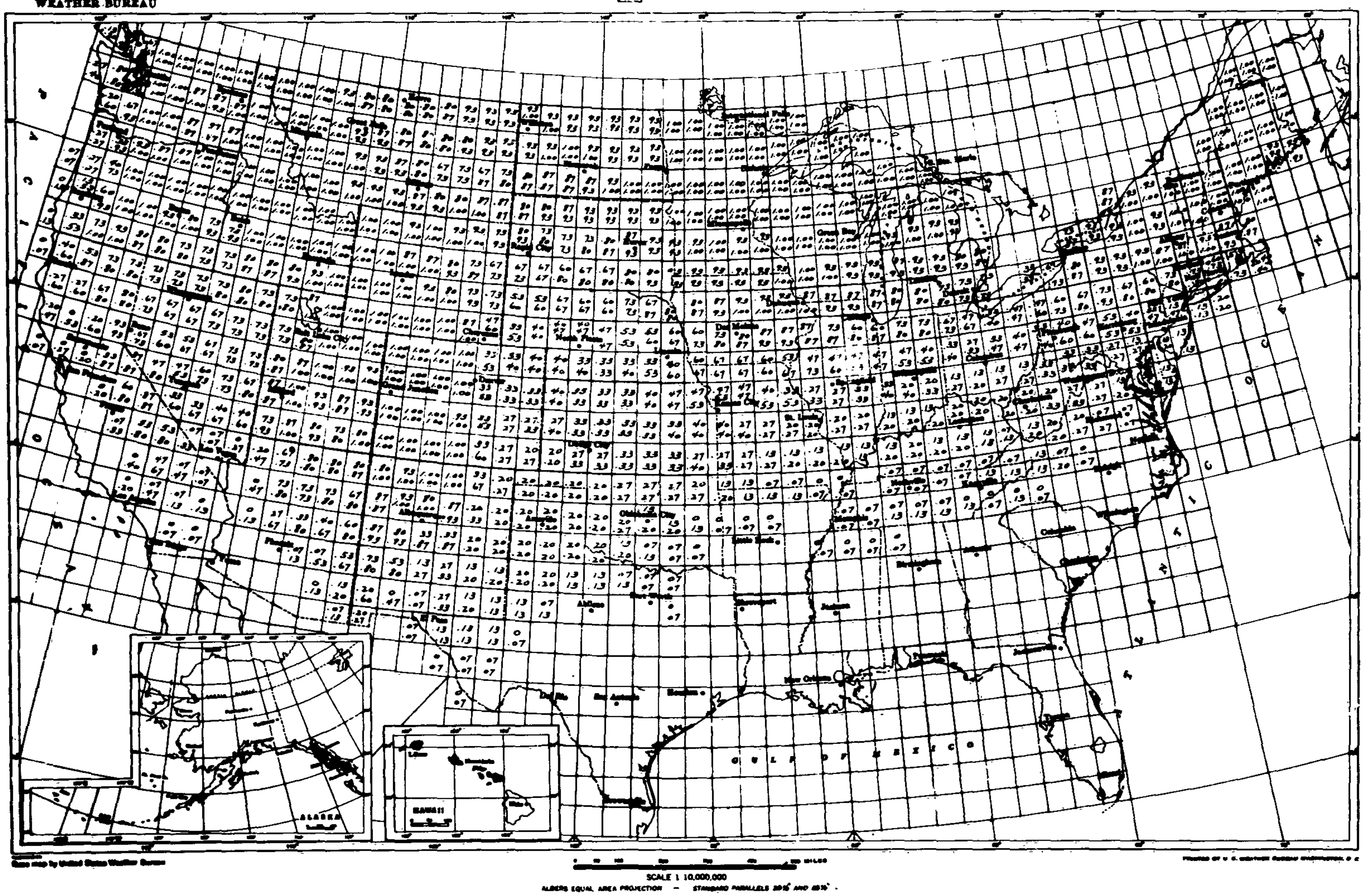
ALBERS EQUAL AREA PROJECTION — STANDARD PARALLELS 29½° AND 45½°

UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

February 5

T - PROBABILITY OF SQUARE OVER 1/2 COVERED.
P - PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

February 12

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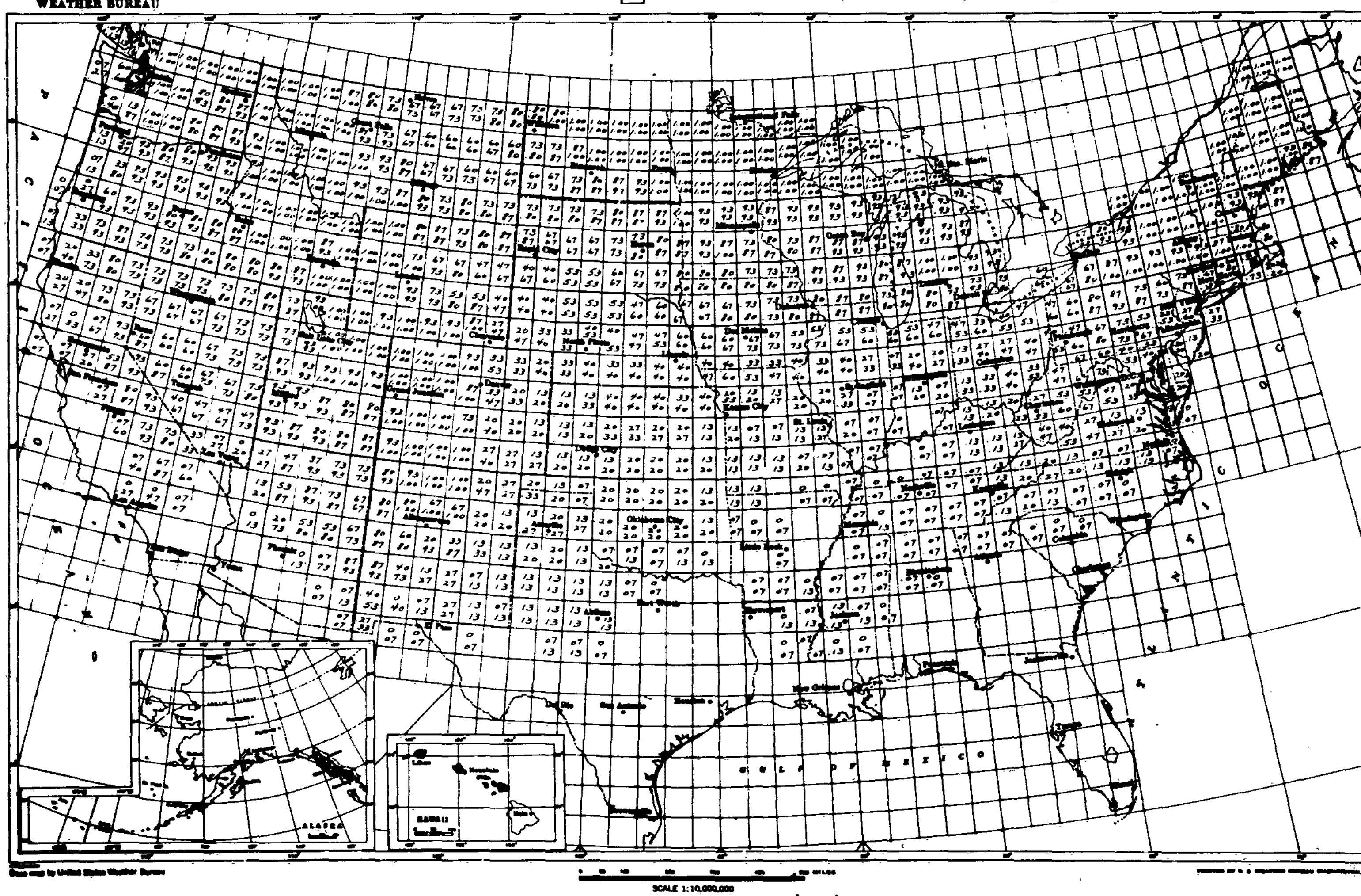
P = PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE.

February 19

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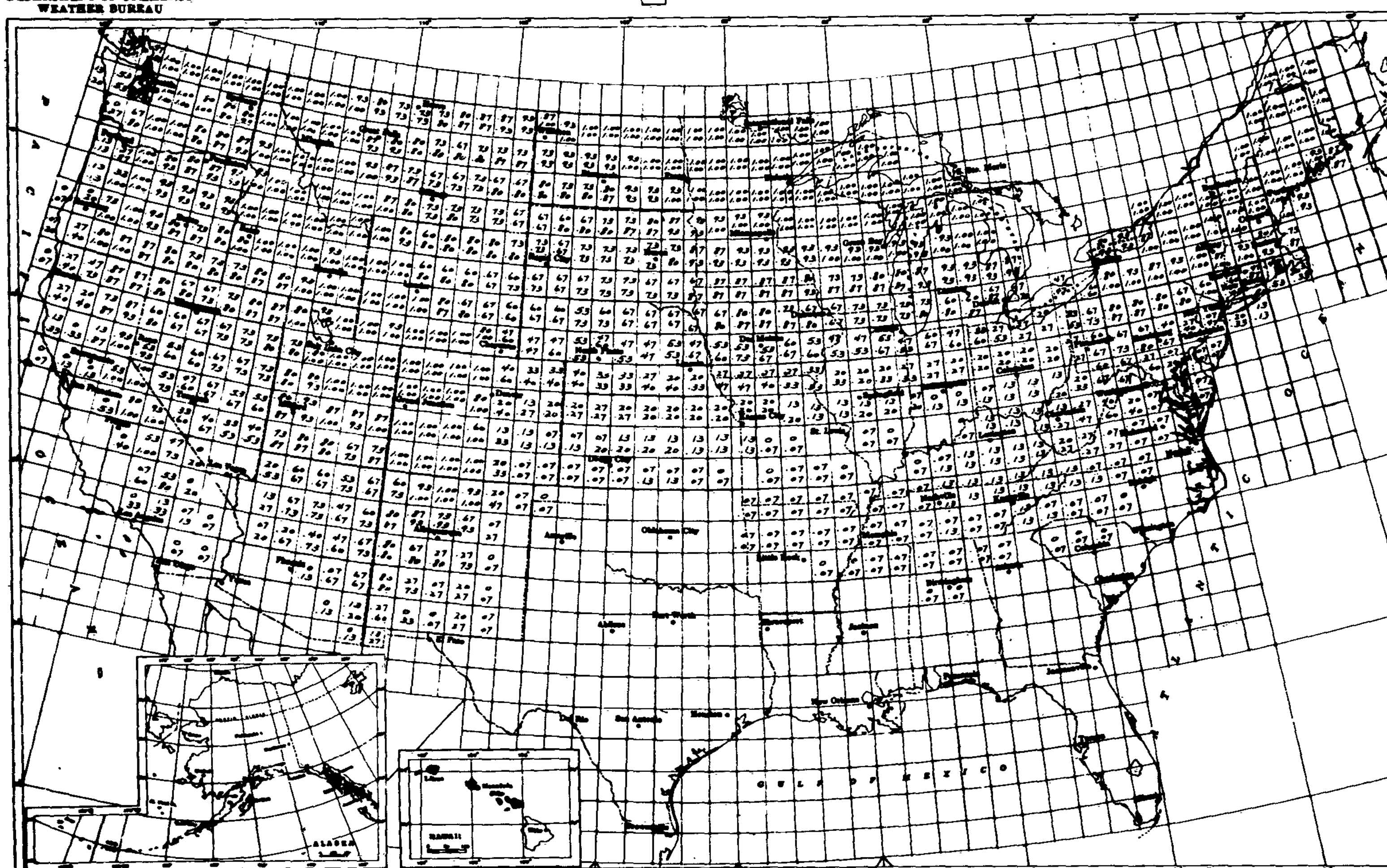
P = PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



SCALE 1:10,000,000
ALBERS EQUAL AREA PROJECTION — STANDARD PARALLELS 29½° AND 45½°

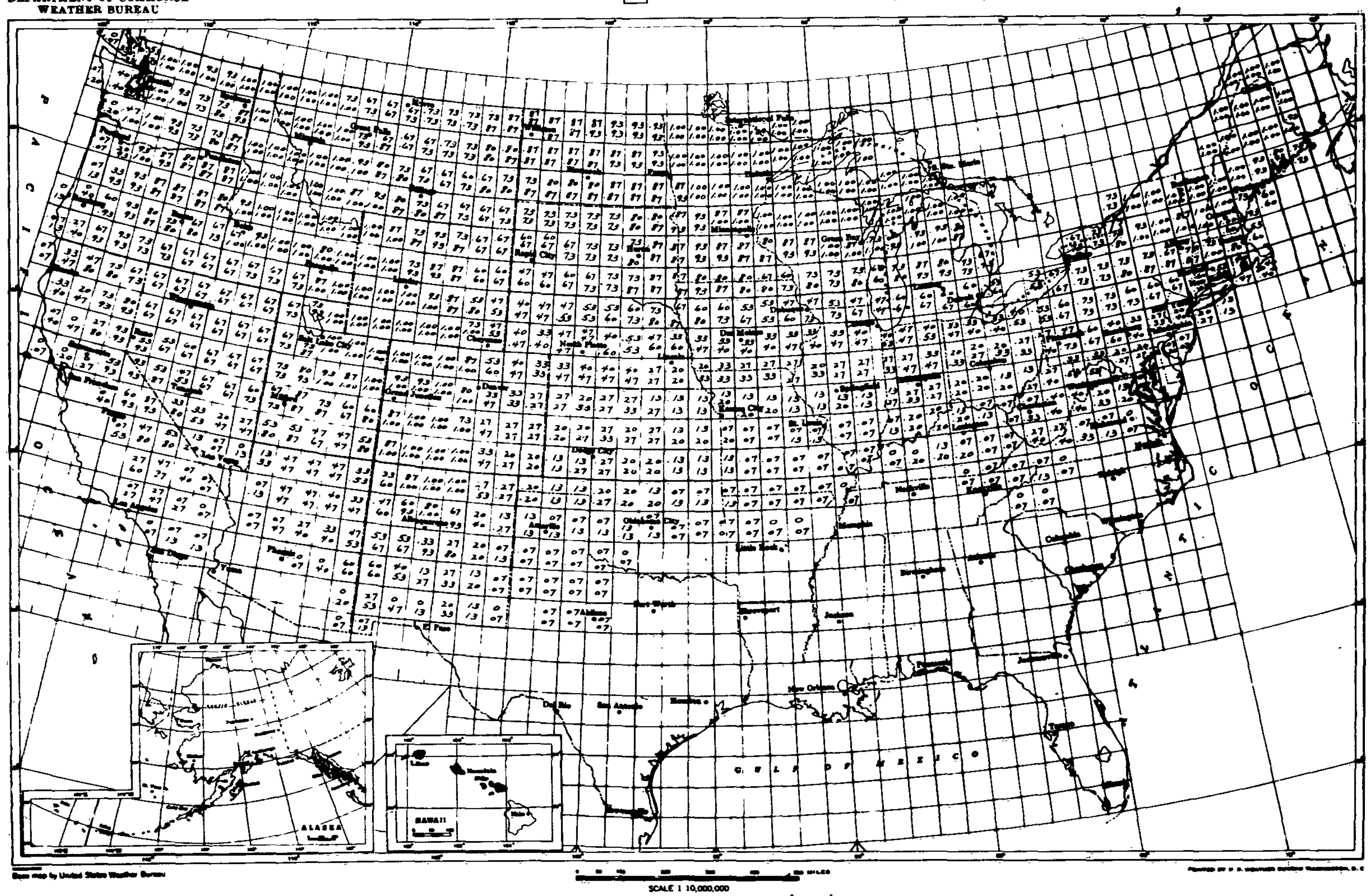
UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

FEBRUARY 26

T
P

T - PROBABILITY OF SQUARE OVER 1/2 COVERED.
P - PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

March 5

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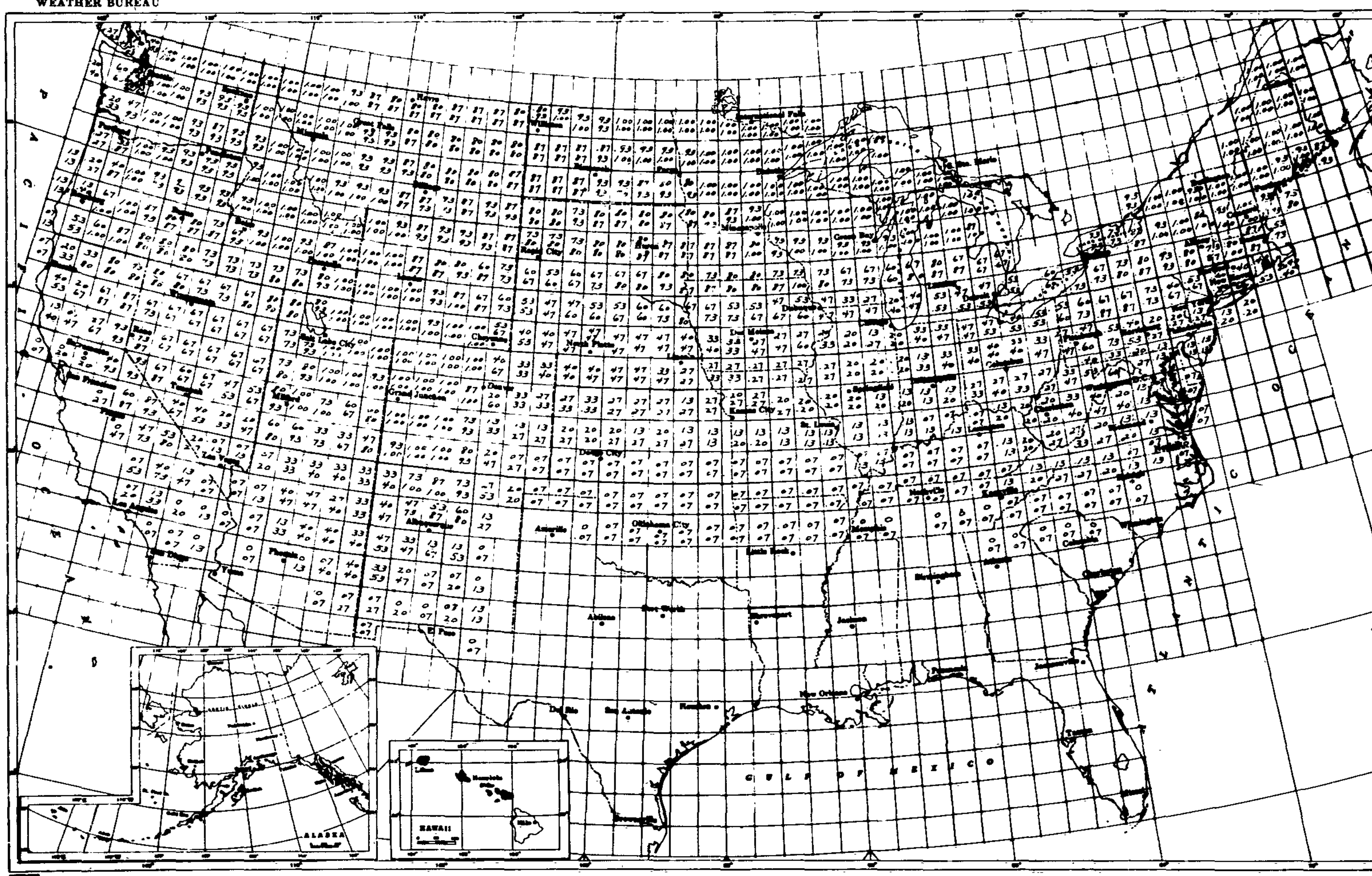
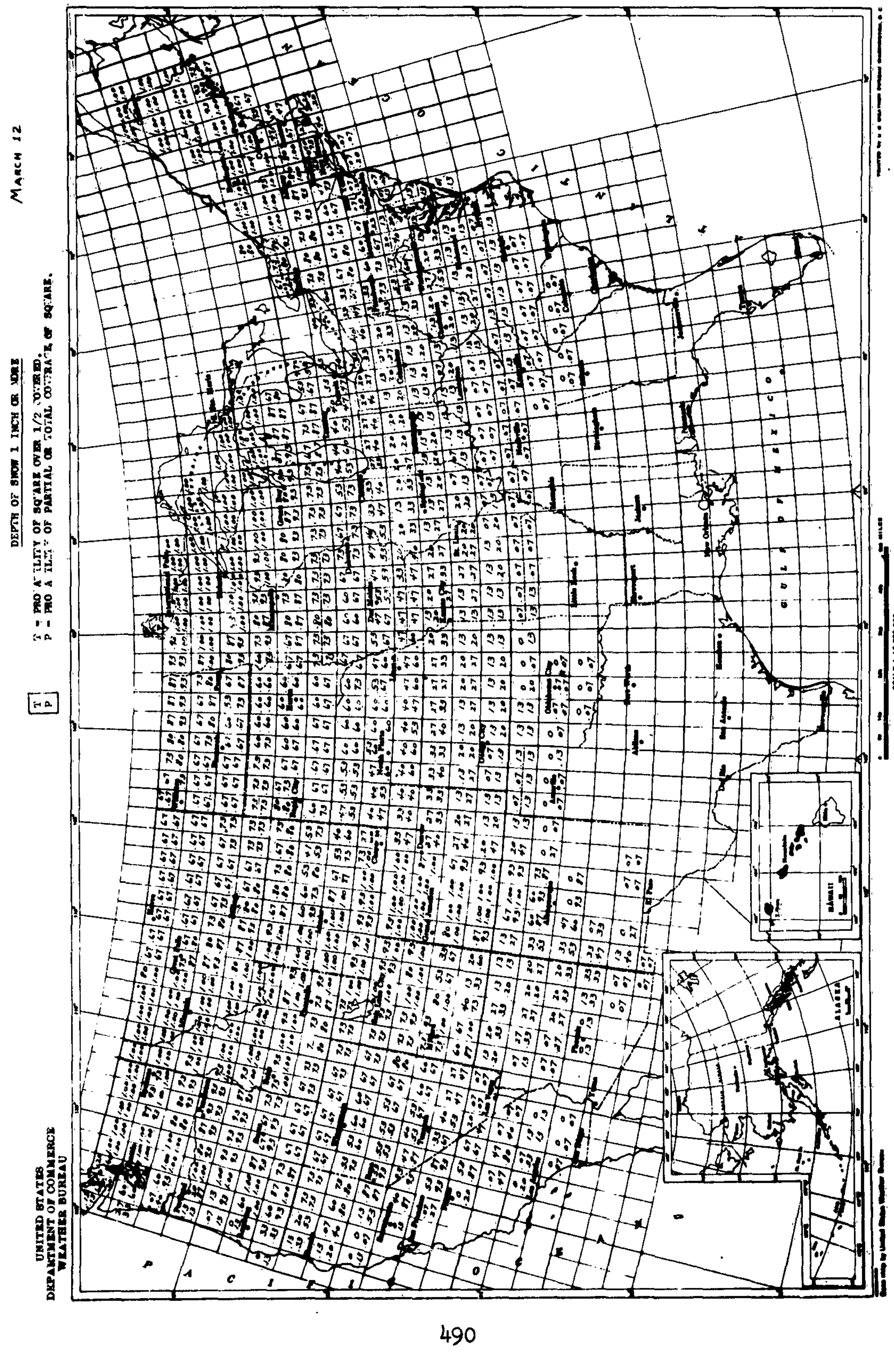
P - PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



Base map by United States Weather Bureau

SCALE 1:10,000,000
ALBERS EQUAL AREA PROJECTION — STANDARD PARALLELS 29½° AND 45½°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DEPARTMENT OF COMMERCE
WEATHER BUREAU
DEPTH OF SNOW 1 INCH OR MORE
T = PROBABILITY OF SQUARE OVER 1/2 COVERED.
P = PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.
MARCH 12
SCALE 1:10,000,000
ALBERS EQUAL AREA PROJECTION — STANDARD PARALLELS 29½° AND 45½°
PACIFIC OCEAN
GULF OF MEXICO
ATLANTIC OCEAN
HAWAII
ALASKA

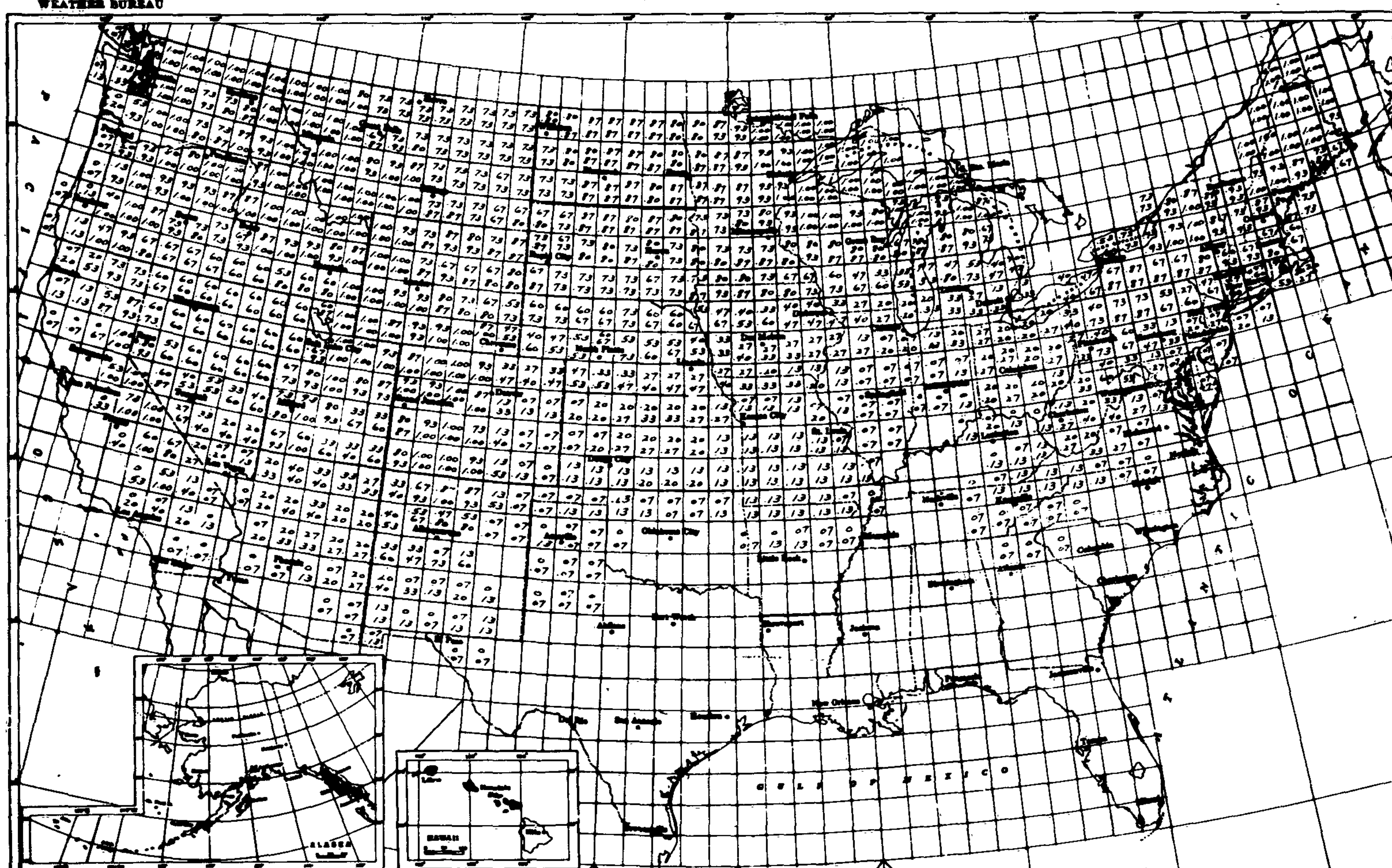
UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

MARCH 19

T
P

T - PROBABILITY OF SQUARE OVER 1/2 COVERED.
P - PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



SCALE 1:10,000,000
ALBERS EQUAL AREA PROJECTION - STANDARD PARALLELS 29½° AND 45½°

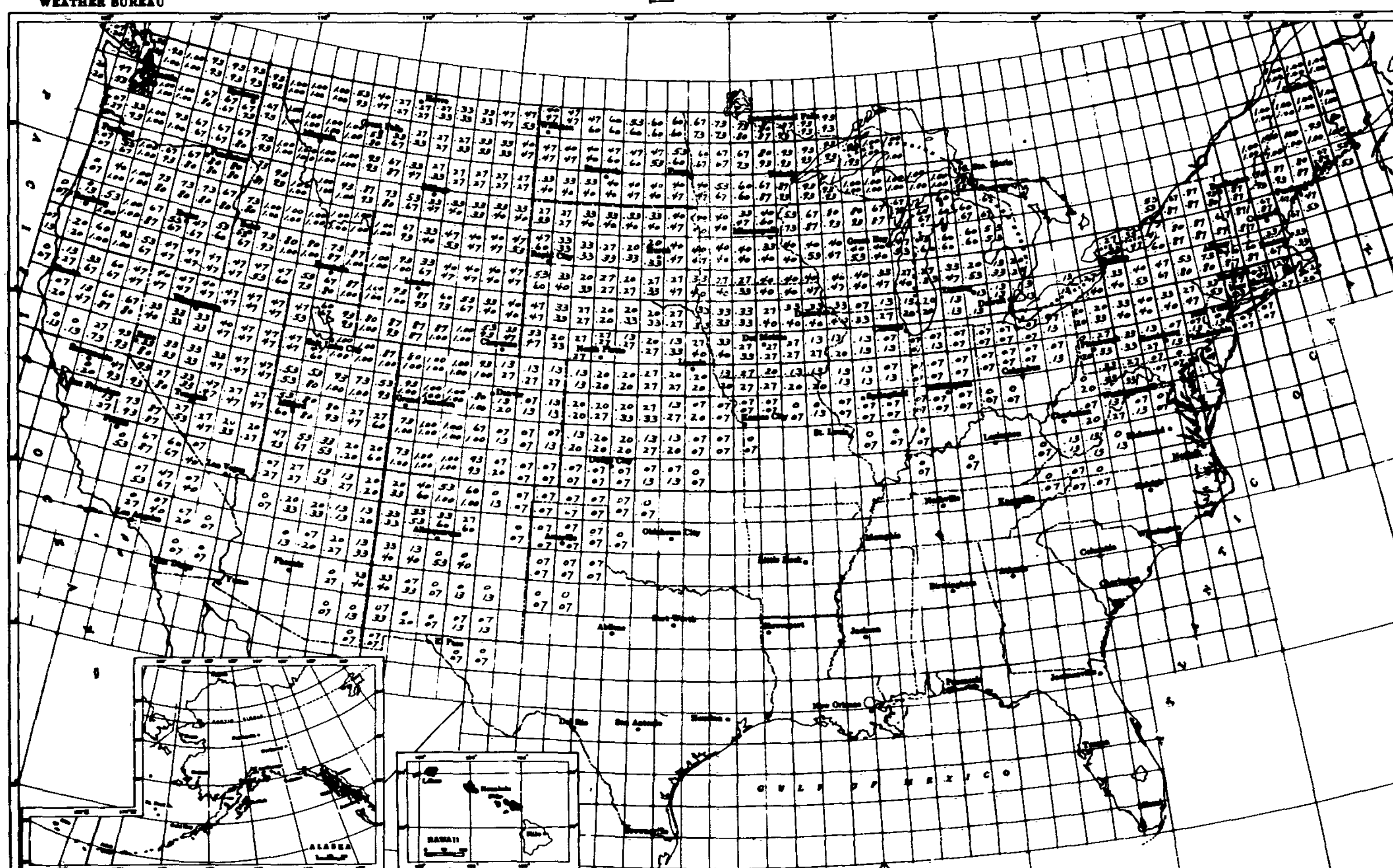
UNITED STATES
DEPARTMENT OF COMMERCE
WEATHER BUREAU

DEPTH OF SNOW 1 INCH OR MORE

MARCH 26

T
P

T - PROBABILITY OF SQUARE OVER 1/2 COVERED.
P - PROBABILITY OF PARTIAL OR TOTAL COVERAGE OF SQUARE.



SCALE 1:10,000,000
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1 Director, Office of Emergency Planning
1 Joseph D. Coker, Office of Emergency Planning
11 Committee on Fire Research, National Academy of Sciences-National Research Council
1 Richard Park, National Academy of Sciences-National Research Council
1 Library, Woods Hole Institute of Oceanography, Woods Hole, Mass.
3 Federal Fire Council
150 Scientific Documentation Division, U. S. Weather Bureau
Miscellaneous Non-Government:
1 Chief, EPS Division, Institute for Defense Analysis
1 Chief, R&E Support Division, Institute for Defense Analysis
1 Library, Institute for Defense Analysis
1 American Institute for Research, Pittsburg, Pa.
1 American Municipal Association
1 Dikewood Corp., Albuquerque, N. M.
1 Dunlap & Associates, Inc., Stamford, Conn.
1 Civil Defense Library, University of Florida, Gainesville, Fla.
1 R. Meyerott, Lockheed Missiles and Space Co., Palo Alto, Calif.
1 Civil Defense Library, University of Georgia, Athens, Ga.
1 Advance Research, Inc., Needham Heights, Mass.
1 Hudson Institute, Harmon-on-Hudson, N. Y.
1 Ionics, Inc., Cambridge, Mass.
1 General American Transportation Corp., Niles, Ill.
1 National Fire Protection Association Library, Boston, Mass.
1 Operations Research, Inc., Silver Spring, Md.
1 Operations Research, Inc., Santa Monica, Calif.
1 Planning Research Corporation, Englewood Cliffs, N. J.
1 Research Triangle Institute, Durham, N. C.
1 Director, Operations Planning Research Center, Stanford Research Institute, Menlo Park, Calif.
1 System Development Corp., Santa Monica, Calif.
1 William N. Cox, Jr., Georgia Institute of Technology, Atlanta, Ga.
1 Keith Royer, Iowa State University, Ames, Iowa
1 Robert C. Byrus, University of Maryland, College Park, Md.
1 Elmer L. Johnson, Oklahoma State University, Stillwater, Okla.
1 John Bryan, University of Maryland, College Park, Md.
1 G. L. Maatman, Illinois Institute of Technology, Chicago, Ill.
1 Robert E. O'Brien, Bio-Dynamics, Inc., Cambridge, Mass.
1 J. C. Robertson, Internat. Society of Fire Service Instructors, College Park, Md.
1 J. B. Smith, Factory Mutual Research Corp., Norwood, Mass.
1 Mathew M. Braidech, National Board of Fire Underwriters, New York, N. Y.
1 Library, Factory Insurance Association, Hartford, Conn.
1 Library, Underwriters' Laboratories, Inc., Chicago, Ill.
2 American Mutual Insurance Alliance, Chicago, Ill.
1 National Safety Council, Chicago, Ill.
1 Technical Operations, Inc., Burlington, Mass.
1 United Research Services, Inc.
1 Director, Civil Defense Research Center, IIT-Research Institute, Chicago, Ill.
1 The Rand Corporation, Santa Monica, Calif.
1 Engineering Library, University of Maryland, College Park, Md.

Schroeder, Mark J., et al.
1964. SYNOPTIC WEATHER TYPES ASSOCIATED WITH CRITICAL FIRE WEATHER. U.S. Forest Serv., Pacific SW. Forest & Range Expt. Sta., Berkeley, Calif. 492 pp., illus.

ABSTRACT: Mass fires are likely to spread rapidly and burn intensely when strong winds are combined with low humidities and high temperatures, particularly after a rainless period. To identify synoptic weather types that create such periods of critical fire weather, the 48 contiguous states were divided into 14 regions, and fire danger indexes were computed from weather data at 89 stations for the years 1951-60. Surface weather types and upper-air patterns associated with high fire danger are described for each region.

Descriptors:
Meteorology
Weather Forecasting
Atmospheric Motion
Fires (Urban Areas)
Forest Fire
Fire Danger
Fire Weather

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